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DYNAMICS OF TWO-DIMENSIONAL EYE-HEAD TRACKING

by

Andrew U. Meyer

ELECTRICAL ENGINEERING DEPARTMENT

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This research is concerned with two-dimensional target tracking, where eye and/or head motion is used for control. Particular attention has been devoted to a tracking method involving electrooculagraphy (EOG) and to two tracking schemes using a Honey-well remote oculometer, one with and one without a visual feedback display. Each of these tracking methods involves eye-head coordination, but in different ways. During the Summer of 1979, experimental work was carried out at the tracking laboratory of the Aerospace Medical Research Laboratory at Wright-Patterson AFB. The tests, conducted with fifteen human subjects, involved tracking of targets in

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1. INTRODUCTION

Increasing demands on pilots for vehicle control and other functions have made it desirable to supplement the use of hands and feet for manual control by other means, especially for secondary tasks. Utilization of eye and head movement for this purpose has been considered for some time.[1-7] Potential applications may include not only navigational tasks and fire control, but also the selection of information displays or function switches.

In head pursuit tracking systems,[1-3] control is exerted from signals derived from head position sensors. Visual display of the positions of both target and controlled device enables the operator to reduce their difference by corrective head movement.

Target tracking by eye movement is also possible but practical only if the head is not constrained. The Honeywell Remote Oculometer,[4] based on corneal reflection, measures line-of-sight within one degree accuracy, permitting the head to be located anywhere within one cubic foot of a specified location. Thus, the tracking dynamics involve both eye and head motion. The accuracy of $\pm$ 1 degree makes it possible to track without the need for visual feedback. Thus, the operator can track by simply looking at the target, relieving him from the task of conscious error correction. On the other hand, in its present state, the oculometer is rather sensitive in its operation. If operated without visual feedback, extensive calibration will be required.

A setup in the tracking laboratory of the Aerospace Medical Research Laboratory (AMRL) at Wright Patterson Air Force Base (WPAFB) incorporates the above tracking instrumentation. Displays of target and visual feedback are provided in the form of red spots, projected to a large cloth screen from two low-power lasers via pairs of x-y galvanometer-mirrors. The subject sits in a chair approximately 3 meters

away from the screen, which provides a visual field of approximately ± 20o each in vertical and horizontal direction. In addition to computing equipment which is part of the tracking instruments, the laboratory features a PDP 11/34 minicomputer with associated A/D and D/A channels. The setup also contains analog computer equipment, signal generators, both deterministic and random, as well as relevant measuring equipment, which can all be appropriately connected, if and when needed, on a patch panel.

The PDP 11/34 minicomputer can be used both for target signal generation and for data analysis, for which programs have been developed by and for AMRL. Target motion can be provided from programs that calculate and generate quasi-random signals in the form of sum-of-sine waves,[8,9] for given specifications. During a tracking run, the computer provides the signals driving the galvanometers for both target and visual feedback spots and receives the signals from the tracking instruments (e.g., oculometer). All signals, for both azimuth and elevation, are stored on disk for further analysis.

Data analysis capability includes programs for statistical evaluation and for computation of the frequency response of the subject's tracking performance. The statistical evaluation provides information on the portions of time during a run during which the tracking error remained within certain bounds; it also computes the 50% CEP (circular error probability), which defines the radius about the target within which the tracking error remained within 50% of the run-time. The frequency response analysis provides not only gain and phase spectra (in the describing function sense), but also prints out the spectra of correlated and remnant powers for target, control (response) and error signals.

The facility has been used in experiments involving head tracking by helmet-mounted sight,[2,3,5] as well as eye-head tracking using the Honeywell remote oculometer.[4,5,6,7] For both methods, closed-loop gains have been reported that appear reasonably flat up to 1 Hz with half-power handwidths around 1.5 Hz.[2,5,6,7] These reports also show coherence functions* above 0 75 for frequencies up to 1.5 Hz, except for one report on single-axis eye tracking,[6] where the coherence function lies between 0 5 and 0.82 High coherence function values (close to one) suggest linear behavior.

Of the above reports, one also deals with the effect of target angle size on (helmet) head tracking,[2] showing that an increase of target-angle envelope causes a large increase of closed-loop tracking gain. However, this effect appears to be limited to the gain-level itself, not its function of frequency nor the frequency responses of the closed-loop phase and of the coherence function (about 0.75) which all remain roughly the same. No explanation has been presented.

An increase of closed-loop gain with target-size suggests the possibility of nonlinear saturation in the feedback path of the tracking loop, perhaps in the human sensing mechanism. However, before attempting any such modelling, a thorough experimental investigation of the target size effect would be indicated (reference 2 presented preliminary data for helmet tracking on only 3 subjects). For eye-head tracking (using the remote oculometer) no previous data were available on the effect of target-level.

The results of the present project (see Sections 7 and 8) indicate a slight increase of closed-loop tracking gain with maximum target level for eye-head tracking using the oculometer. On the other hand, for another tracking scheme using electroculography (EOG) introduced in Section 3, a slight closed-loop gain decrease for increased target level was found The present results also show that

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*The coherence function, $\gamma^2 = |\text{cross power density between input and output}|^2 / (|\text{power-density of input}|\ |\text{power-density of output}|)$ represents the proportion of input power contained in the output power. Its range is $0 \leq \gamma^2 \leq 1$.

an increased target-level will result in increased bandwidth for oculometer tracking and decreased bandwidth for EOG tracking.

2. SCOPE OF THE PROJECT

The objective of this research is to evaluate experimental data relevant for the development of a describing function model of eye-head tracking, including the effect of target-level. The data were obtained during the Summer of 1979 at the AMRL tracking laboratory.

Originally. this investigation was to concentrate on tracking with the Honeywell remote oculometer. However, due to unexpected delays and problems connected with a move of the tracking laboratory facility between buildings. that instrument did not become operational until August 8, 1979, near the end of the investigator's stay. When it became apparent that the oculometer could not be used in time to conduct a sufficient number of tracking experiments, the investigator proposed a different eye-head tracking method based upon electrooculography (EOG) and proceeded to conduct tracking tests on human subjects, using the target generating and data processing facility of the AMRL tracking laboratory. When the oculometer finally became operational, tracking tests were expanded to include both oculometer and EOG tracking.

The objective thus was to conduct tracking experiments with targets varying randomly in both horizontal and vertical direction, using different target angle envelopes in order to determine possible nonlinear behavior. The recorded data have been used to model both EOG tracking and oculometer tracking in terms of its describing function representation.

All oculometer tracking experiments were conducted with and without visual feedback, in order to compare performance of tracking by just looking at the target (without visual feedback) and tracking (with visual feedback) where the subject must consciously control the feedback image to align with the target image. EOG tracking is practical only with visual feedback.

3. EOG TRACKING

Electrooculography (EOG) is a method for measuring (both horizontal and vertical) eye orientation.[9,10] Its chief advantage is its simplicity; other assets include its fast speed of response and the large angular range. On the negative side are problems with d-c drift of the EOG responses and inaccuracy.

It is not the intention here to claim EOG as a better alternative to existing transducer methods for tracking, but rather to examine some basic properties of EOG tracking. The EOG tracking scheme investigated in this research calls upon different tasks for the human operator than other methods. They involve eye-head coordination and EOG tracking tests may provide a tool for the study of their dynamics.

Since eye-position sensing by EOG is inherently inaccurate one may be tempted to dismiss EOG for use in target tracking. However, one should realize that the accuracy of any (eye-position) sensor will be of very little significance if its output is used to control the visual feedback display. It is the human operator who performs the measuring by perceptual means. This, of course, is true for any tracking scheme incorporating visual feedback including head-tracking. The sensor-inaccuracy will merely affect the open-loop gain with relatively little effect on the (closed-loop) tracking performance. Likewise, the drift of the EOG potential does not affect the tracking accuracy and should be tolerable as long as it stays within a reasonable range in the visual field. Though the drift was tolerable for the EOG tracking experiments performed in the laboratory, it is believed that it can be reduced by careful choice of electrodes; even if not, its effect can be reduced by electronic means.

Electrooculography is based upon an electrical d-c potential difference between the front (positive) and back (negative) of the eye. Electrodes placed

across an eye will pick up a d-c potential roughly proportional to the eye orientation angle, with a sensitivity of the order of 20 microvolt per degree.

In the tracking experiments conducted during this research, vertical orientation (elevation) was picked up from electrodes placed above and below one eye, whereas horizontal orientation (azimuth) was picked up by electrodes placed outside of both eyes. An electrode placed on an ear lap was connected to the ground. The vertical and horizontal electrode pairs were connected to d-c amplifiers which, in turn, drove the mirror-galvanometers to provide the feedback display spots.

Depending on the polarity of the feedback connection, two different modes of EOG tracking are possible, which shall be called (a) *eye control mode* and (b) *head control mode*, to emphasize the dominant motion involved.

(a) Eye Control Mode: Here, eye motion causes the feedback display spot to move in the same direction, when the head is fixed. However, when the eye line-of-sight is fixed, head motion will cause the display spot to move in the opposite direction. It will thus be natural for a human to try tracking by eye motion, while keeping the head as steady as possible, except for corrective control motion in the opposite direction.

(b) Head Control Mode: Here, the display spot is moved in the same direction as the head motion (when the eye line-of-sight is fixed), or in the direction opposite to eye motion (when the head is fixed). In this mode, it turns out to be natural to use head motion for tracking, unconsciously using small eye motion for corrective control.

It was found that the head control mode is easier to perform, at least for tracking tasks requiring freedom of head position. It was therefore decided to devote the experimental work in this project to the head control mode.

Furthermore, it was decided to perform the experimental series with an overall open-loop gain of one. The gain adjustment is performed as follows: The subject is

asked to keep his head in a fixed position and to alternate his eye fixation between two locations on the screen (12 degrees apart from each other), while the amplifier gain is adjusted such that the display spot controlled by the eye movement alternates over the same distance (though in opposite direction for the head-control mode). The subject is instructed not to pay attention to the display spot during the calibration procedure. It is also possible to bias the display such that it is away from the subject's view during calibration.

The same procedure can be used to obtain any other gain value. The unity gain chosen for this experimental series appears to be a reasonable compromise between "loose control" (for toolow gain) and sensitivity to disturbances (for too much gain). However, more investigation will be required to determine the optimum choice of gain.

4. EXPERIMENTS CONDUCTED DURING THE SUMMER OF 1979

One hundred tracking runs were recorded for 15 subjects (9 female and 6 male) between the ages of 18 and 62, of which one subject was tested, in a preliminary series, for the effect of random target forcing functions of different break frequencies. Fourteen (14) subjects were tested for EOG tracking, each at three different target amplitude envelopes (6^o, 9^o and 12^o). Of these, 6 subjects were also tested for tracking with the Honeywell remote oculometer, also at the same three target amplitude envelopes. The 48 oculometer runs were all conducted with and without feedback display (24 each).

In order for the subject to be able to distinguish the target spot from the feedback display spot, the latter was smaller (approximate diameters were 12 mm and 3 mm respectively; the screen was about 3 meters away from the subject). The target was driven in both azimuth and elevation by sum-of-sine functions (10 frequencies), simulating random motion.[8] The frequency ranged between 0.1 and 3.0 Hertz, with a (6 dB) break frequency of 0.8 Hz in all runs for 12 subjects. Earlier EOG tracking runs on two subjects were performed with forcing functions of 1.0 Hz break

frequency; but it was found that 0.8 Hz would be more realistic. The specifications for the target forcing functions used in the experiments are presented in Table A-1, Appendix A.

EOG tracking, as described in Section 3, involves a certain amount of head-eye coordination and constitutes a somewhat more difficult task for the human operator than oculometer tracking (especially oculometer tracking without visual feedback). It therefore requires a certain amount of training. Among the 15 subjects, the time required to acquire a reasonable tracking skill varied between 10 and 30 minutes. Scheduling constraints did not permit any longer training periods which, perhaps, may have improved the tracking scores.

After the training period, each subject did seven tracking runs, each lasting 91 seconds. The first of these, considered a practice run, was performed at a target amplitude envelope of 6 degrees. The subsequent six runs consisted of two runs each with target amplitude envelopes of 6^{o}, 9^{o} and 12^{o}, their sequence being permuted. Also permuted were three forcing functions with equal amplitude characteristics but different (randomly selected) phases (except for each initial [practice] run which used a forcing function differing from the others by its break frequency of 0.7 Hz). The record of the relevant EOG tracking runs is presented in Table A-2, Appendix A.

The tracking tests with the Honeywell remote oculometer were performed on six of the subjects. For each subject, eight oculometer runs were performed; four each without and with visual feedback. For each set of four runs, the first (practice) run had a target amplitude envelope of 6^{o}, the other (regular) three runs were performed at 6^{o}, 9^{o} and 12^{o}, the sequence being permuted, as was the (same) set of three target forcing functions used in the EOG experiments The record of the relevant oculometer tracking runs is presented in Table A-3, Appendix A.

For the oculometer runs with visual feedback, an open-loop gain of one was used. achieved by calibrating the equipment such that the line-of-sight is aligned with the feedback spot (this is part of the normal oculometer calibration procedure).

5. ANALYSIS OF INDIVIDUAL TRACKING RUN DATA

The analysis of the individual tracking run data was done on the PDP 11/34 minicomputer at the AMRL Tracking Laboratory; namely (a) frequency response analysis, using program MODFRT and (b) statistical analysis, using program TR4.* These programs produced evaluations for each test run.

From each tracking run record, the frequency response program (MODFRT) computes spectra of correlated and remnant power for target, control (response) and the error (between target and control), each for both azimuth and elevation. It also provides gain and phase spectra, in the describing function sense. All spectral data are given for the same set of frequencies that generated the target motion by use of the sum-of-sine approach.

The data of interest in this study are the gain-phase spectra. In program MODFRT, the the gain and phase values are obtained from the power sectral data. Thus, for each frequency value, the reliability of the computed gain and phase must be assessed in terms of the correlated power (COR), as well as the ratio of the correlated power to remnant power (C/R). This was done by the classification presented in Table 5-1, which has been used to identify each data point in all of the individual frequency responses.

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*For some of the tracking runs, the analysis was performed during the summer 1979, the remaining computations were performed during August 1980.

TABLE 5-1

RELIABLILITY - LEVELS OF DATA POINTS IN GAIN - PHASE PLOTS

Marking on Plot	Conditions		Reliability Level	Weight Assigned
	$\frac{\text{Correlated Power}}{\text{Remnant Power}} = \frac{C}{R}$	Correlated Power = COR		
○	C/R > 6 dB	COR > -12 dB	GOOD	0
□	C/R > 6 dB	COR < -12 dB	FAIR	1
△	C/R < 6 dB	COR > -12 dB	ACCEPTABLE	2
×	C/R < 6 dB	COR < -12 dB	POOR	3

The individual gain and phase versus frequency plots for the tracking runs on 11 (of the 15) subjects, thus marked, are presented in Appendix A. For each tracking run. frequency response plots are presented for both the closed-loop [Control (output) / Target (input)] and the open-loop [Control (output) / Error (Target - Control)].* Also shown with the plots for each run is the 50% CEP ("circular error probability") which defines the radius, in degrees, within which the tracking error remains within 50% of the run time. It is presented both in reference to the target and in reference to the centroid (of the error motion). These data had been computed by Program TR4 for each tracking run.

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*Since the tracking schemes are not compensatory. the physical meaning of an "open-loop" transfer function is not clearly defined.

6. DATA EVALUATION

The results of the individual tracking runs have been classified and averaged in appropriate categories. All tracking runs for subjects 3 through 14 were performed with forcing functions of the same break frequencies of 0.8, Hertz (see Table A-1, Appendix A for forcing function specifications and Tables A-2 and A-3, Appendix A, for the record of the tracking runs for subjects 1-14). These tracking runs serve as the basis for analysis and model parameter estimation (see Section 7).

Excluded from averaging are the first runs in each series which were considered practice runs. Also excluded are the results of the tracking runs on Subjects 1 and 2 where the break frequency of the forcing function was 1.0 Hertz; these data are not considered reliable enough to warrant consideration for the establishment of models. The break frequency of 1.0 Hertz was evidently too high and subsequent tracking runs for Subjects 3 through 14 were performed with a forcing function break frequency of 0.8 Hertz. Nevertheless, the 12 EOG runs for Subjects 1 and 2 were averaged by themselves and the results are presented in Appendix C.

The results of the remaining 69 EOG and 36 oculometer tracking runs (on Subjects 3 to 14) were averaged in the following groups:

EOG TRACKING RUNS:

For 6 degrees max. target field: 24 runs on 12 subjects
" 9 " " " " : 24 " " 12 "
" 12 " " " " : 21 " " 12 "

OCULOMETER WITHOUT VISUAL FEEDBACK:

6 runs on 6 subjects, each for 6, 9 and 12 deg. max. target field.

OCULOMETER WITH VISUAL FEEDBACK:

6 runs on 6 subjects, each for 6, 9 and 12 deg. max. target field.

Within every given group, for each frequency, averages, standard deviations as well as maxima and minima were obtained for the gain and phase values. Also averaged were their "reliability levels" in terms of the "weights" defined in Table 5-1. These "weights" were then discretized again by the rule defined in Table 6-1 into "reliability levels" of the averaged frequency response plots.

TABLE 6-1

RULE FOR DETERMINING RELIABILITY LEVELS
FOR AVERAGED GAIN AND PHASE PLOTS

MARKING ON PLOT	RANGE OF AVERAGE WEIGHT (AW)	RELIABILITY LEVEL OF AV. GAIN/PHASE VALUES
⬡	0 AW 0.75	GOOD
□	0.75 AW 1.50	FAIR
△	1.50 AW 2.25	ACCEPTABLE
×	2.25 AW 3.00	POOR

Also obtained were the averages and standard deviations of the 50% CEP ("circular error probability") both with respect to the target and to a centroid (of the error motion).

As a summary of the relevant results, Figures 6-1 to 6-9 present the frequency response statistics including the average value and standard deviation for each frequency as well as the average values and standard deviations of the 50% CEP for all runs. The details of this effort are presented in Appendix B. both in tabular form and in terms of frequency response plots.

Figure 6-1

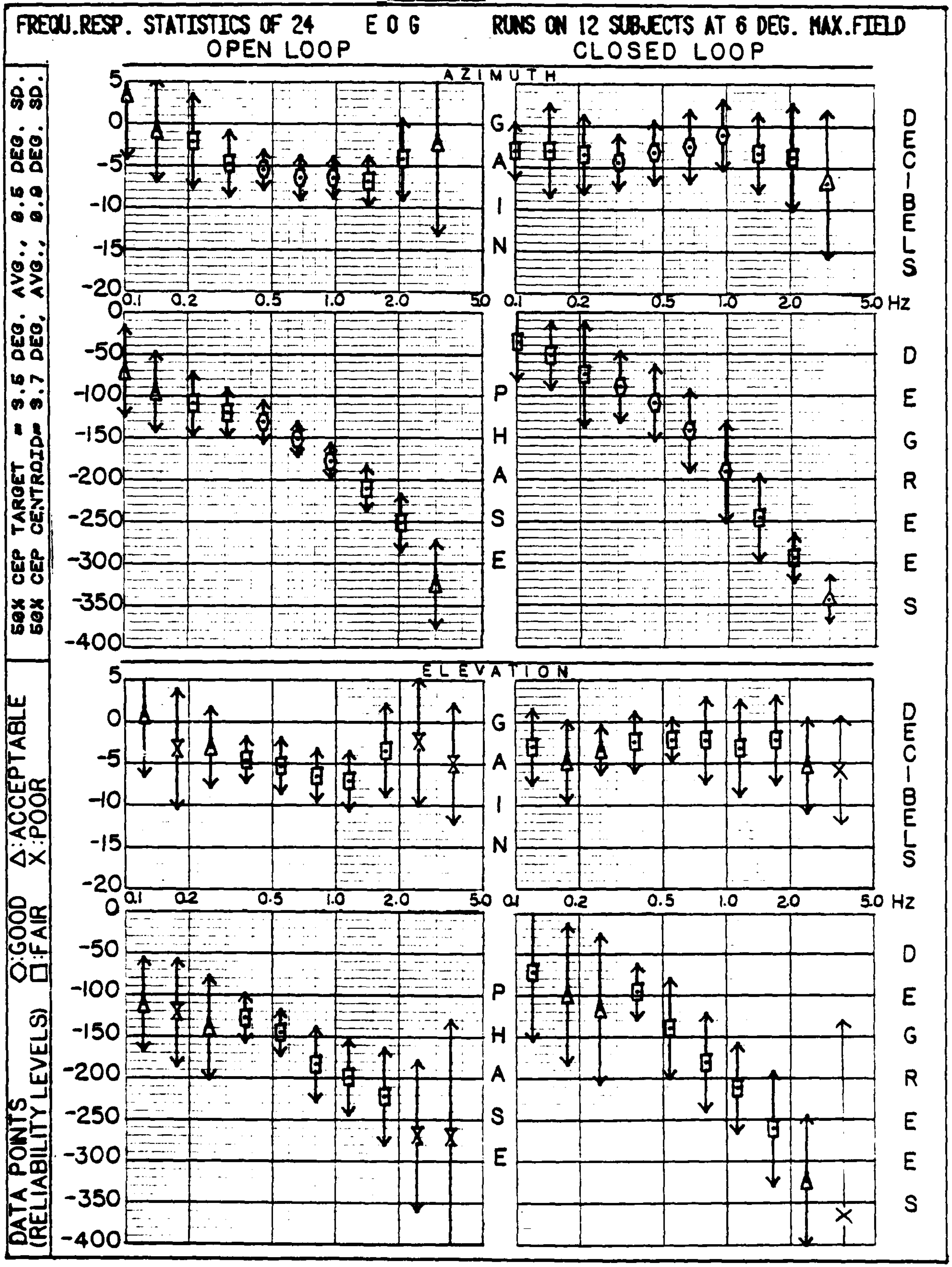

FREQU.RESP. STATISTICS OF 24 E O G RUNS ON 12 SUBJECTS AT 6 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 3.5 DEG. AVG., 6.5 DEG. SD.
50% CEP CENTROID= 3.7 DEG. AVG., 6.9 DEG. SD.
DATA POINTS (RELIABILITY LEVELS) ○:GOOD □:FAIR △:ACCEPTABLE X:POOR

Figure 6-2

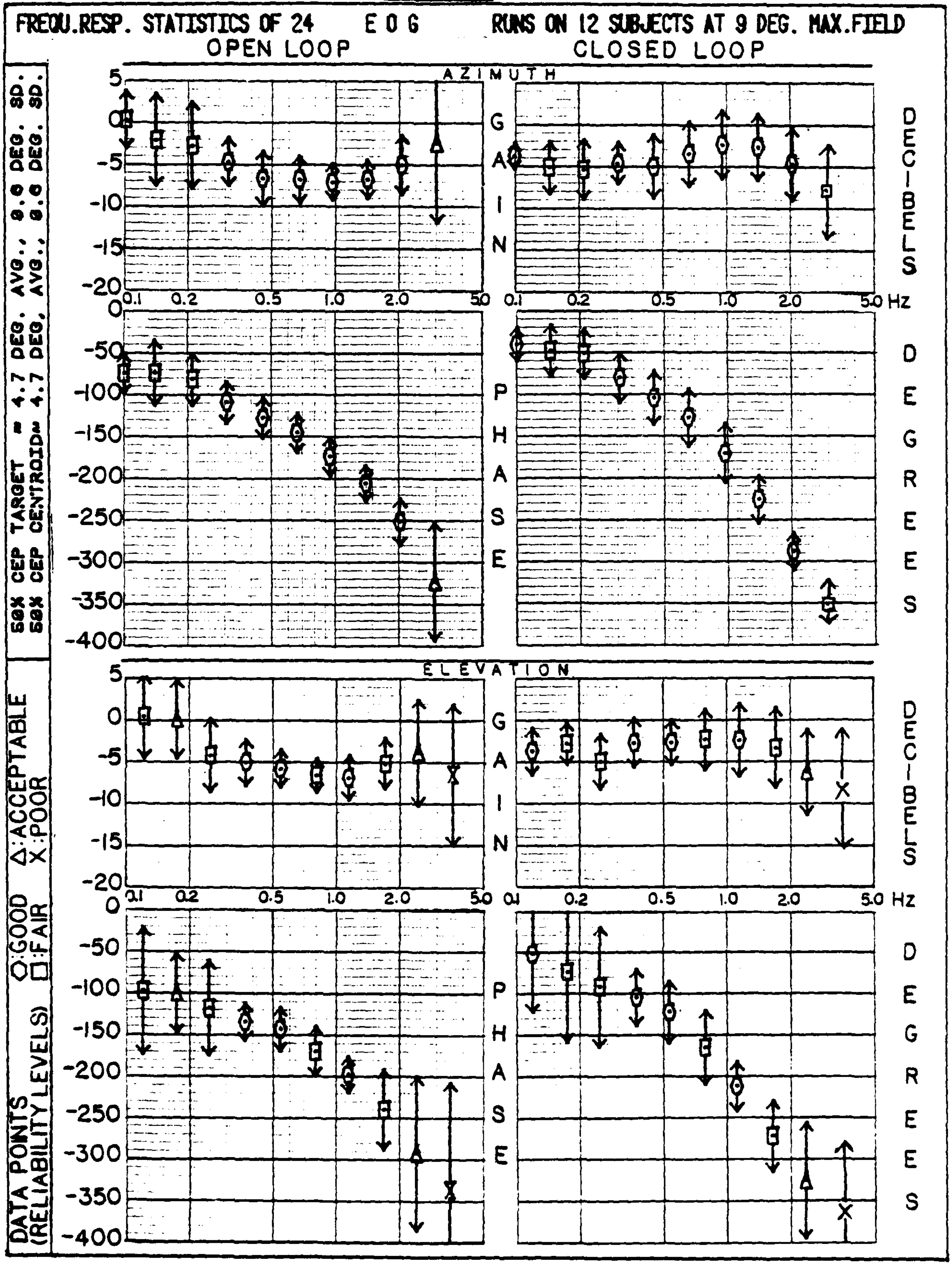

FREQU.RESP. STATISTICS OF 24 E O G RUNS ON 12 SUBJECTS AT 9 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 4.7 DEG, AVG., 9.0 DEG. SD.
50% CEP CENTROID= 4.7 DEG, AVG., 8.6 DEG. SD.
Δ:ACCEPTABLE
X:POOR
O:GOOD
□:FAIR
DATA POINTS
(RELIABILITY LEVELS)

Figure 6-3

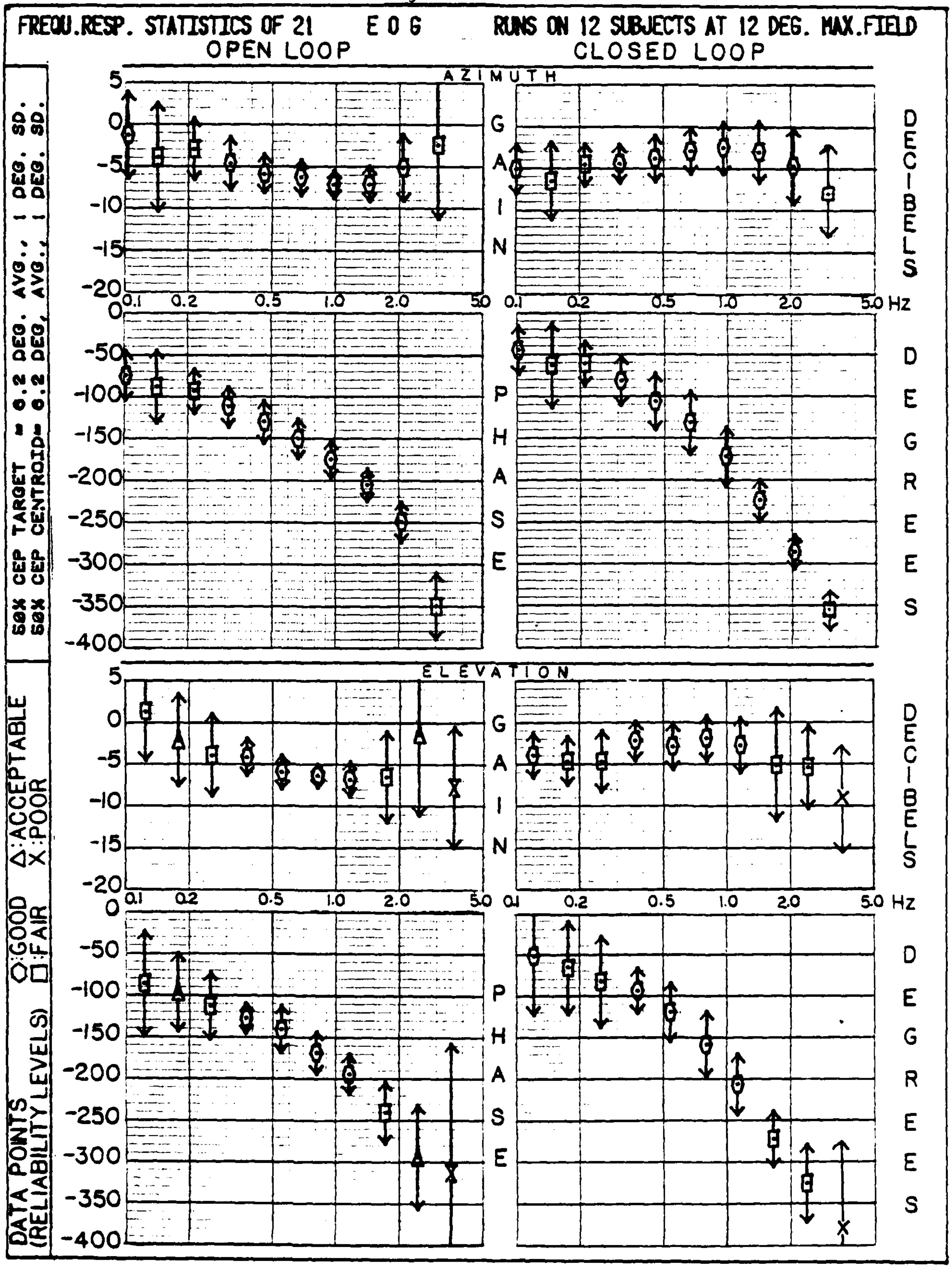

FREQU.RESP. STATISTICS OF 21 E O G RUNS ON 12 SUBJECTS AT 12 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 0.2 DEG. AVG., 1 DEG. SD.
50% CEP CENTROID= 0.2 DEG. AVG., 1 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
○:GOOD □:FAIR
Δ:ACCEPTABLE X:POOR

Figure 6-4

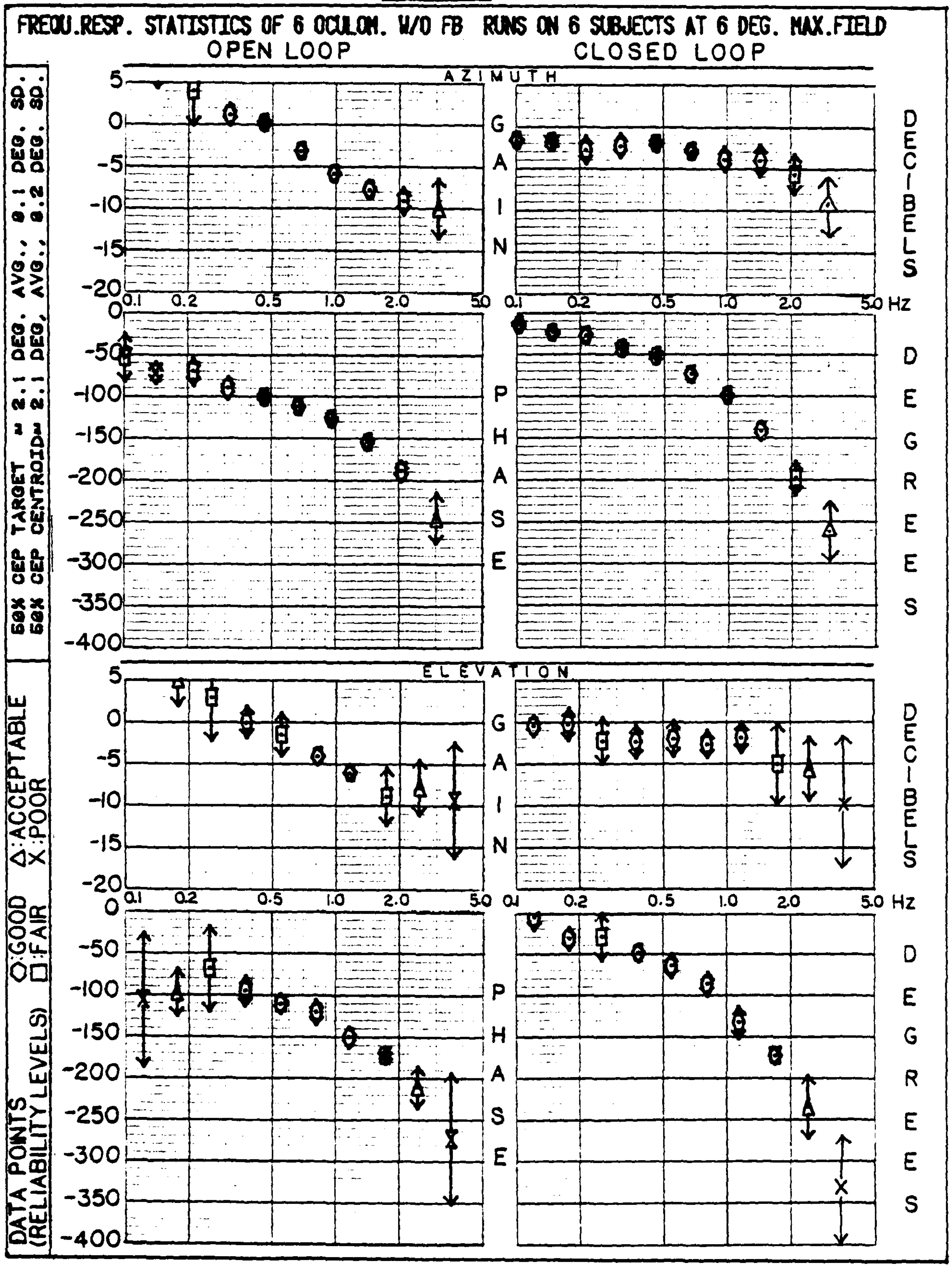

FREQU.RESP. STATISTICS OF 6 OCULOM. W/O FB RUNS ON 6 SUBJECTS AT 6 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 2.1 DEG, AVG., 0.1 DEG. SD.
50% CEP CENTROID= 2.1 DEG, AVG., 0.2 DEG. SD.
DATA POINTS (RELIABILITY LEVELS) O:GOOD □:FAIR △:ACCEPTABLE X:POOR

Figure 6-5

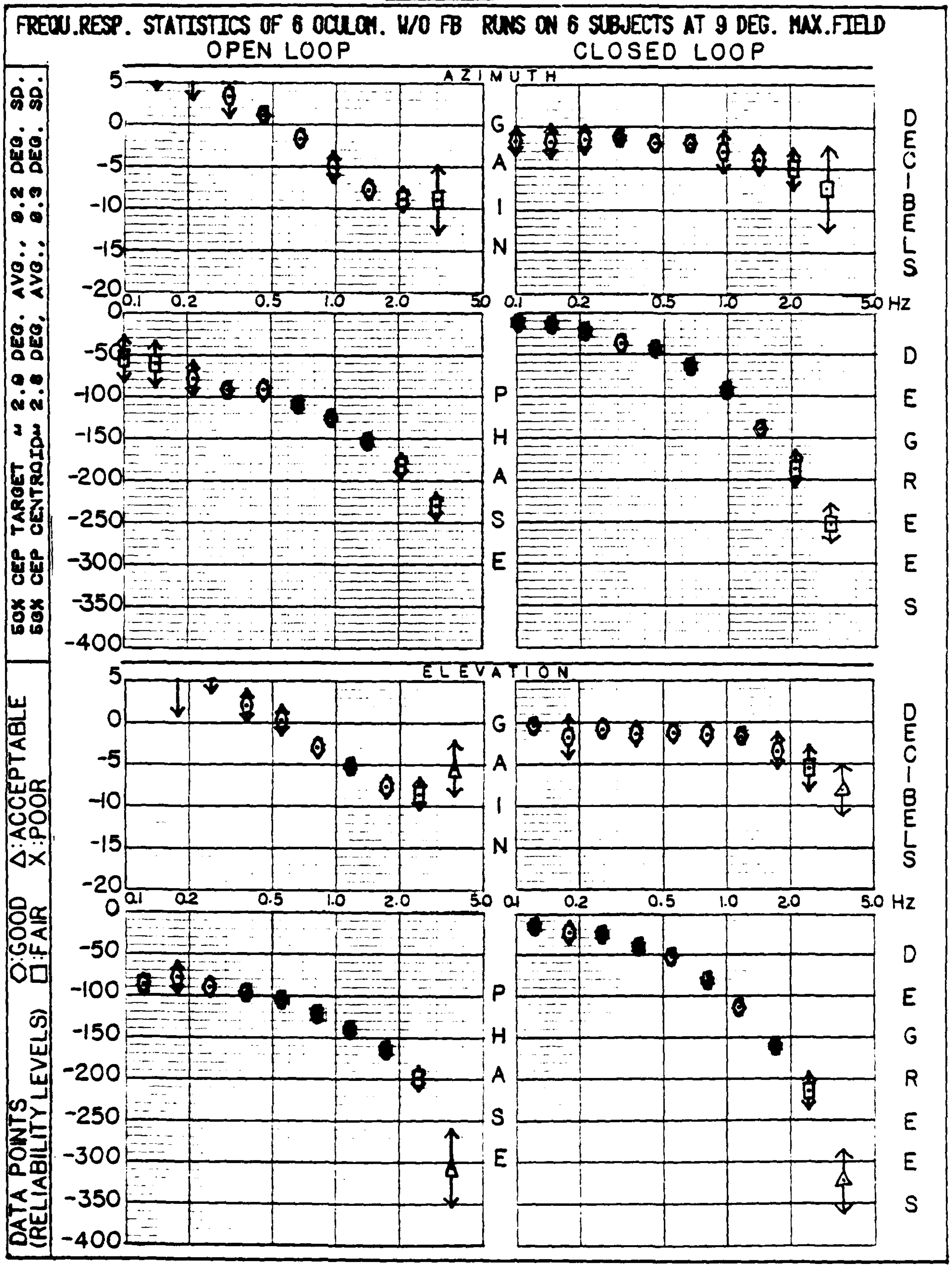

FREQU.RESP. STATISTICS OF 6 OCULOM. W/O FB RUNS ON 6 SUBJECTS AT 9 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 2.9 DEG, AVG., 9.2 DEG. SD.
50% CEP CENTROID= 2.8 DEG, AVG., 9.3 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
O:GOOD
□:FAIR
Δ:ACCEPTABLE
X:POOR

Figure 6-6

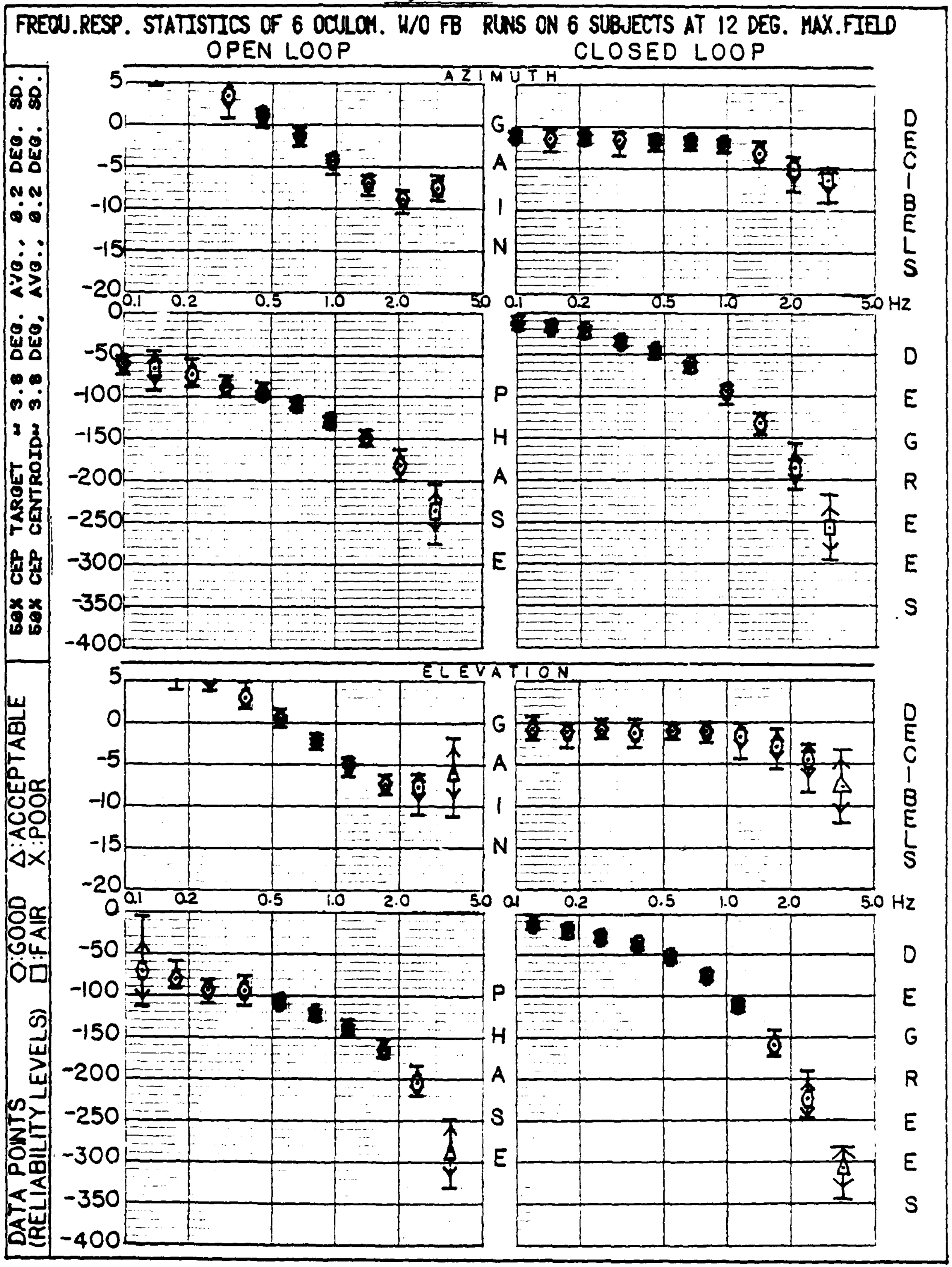

FREQU.RESP. STATISTICS OF 6 OCULOM. W/O FB RUNS ON 6 SUBJECTS AT 12 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 3.8 DEG, AVG., 8.2 DEG. SD.
50% CEP CENTROID= 3.8 DEG, AVG., 8.2 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
O:GOOD
□:FAIR
Δ:ACCEPTABLE
X:POOR

Figure 6-7

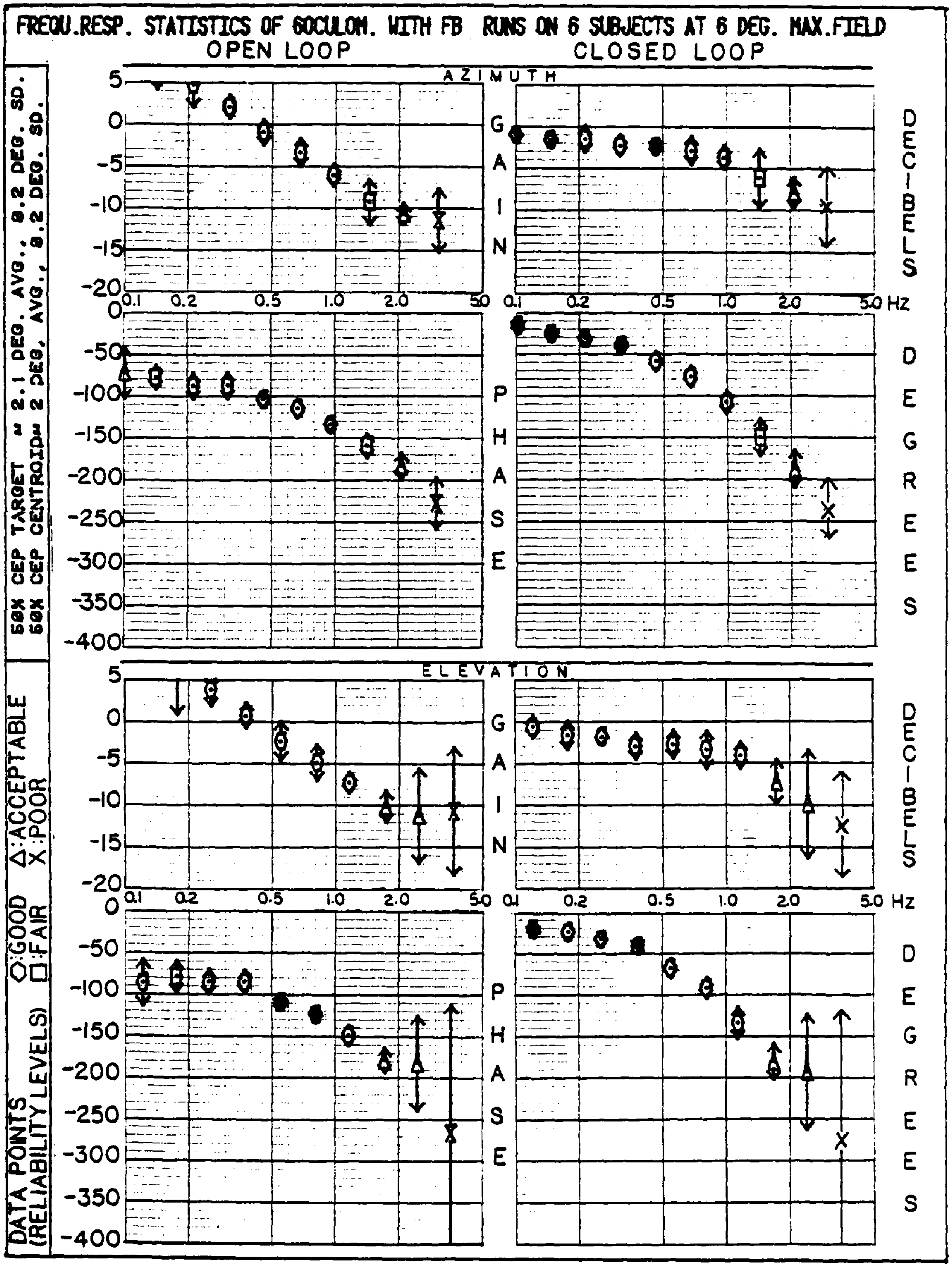

FREQU.RESP. STATISTICS OF 6OCULOM. WITH FB RUNS ON 6 SUBJECTS AT 6 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET " 2.1 DEG. AVG., 3.2 DEG. SD.
50% CEP CENTROID" 2 DEG. AVG., 3.2 DEG. SD.
⬡:GOOD □:FAIR
△:ACCEPTABLE X:POOR
DATA POINTS (RELIABILITY LEVELS)

Figure 6-8

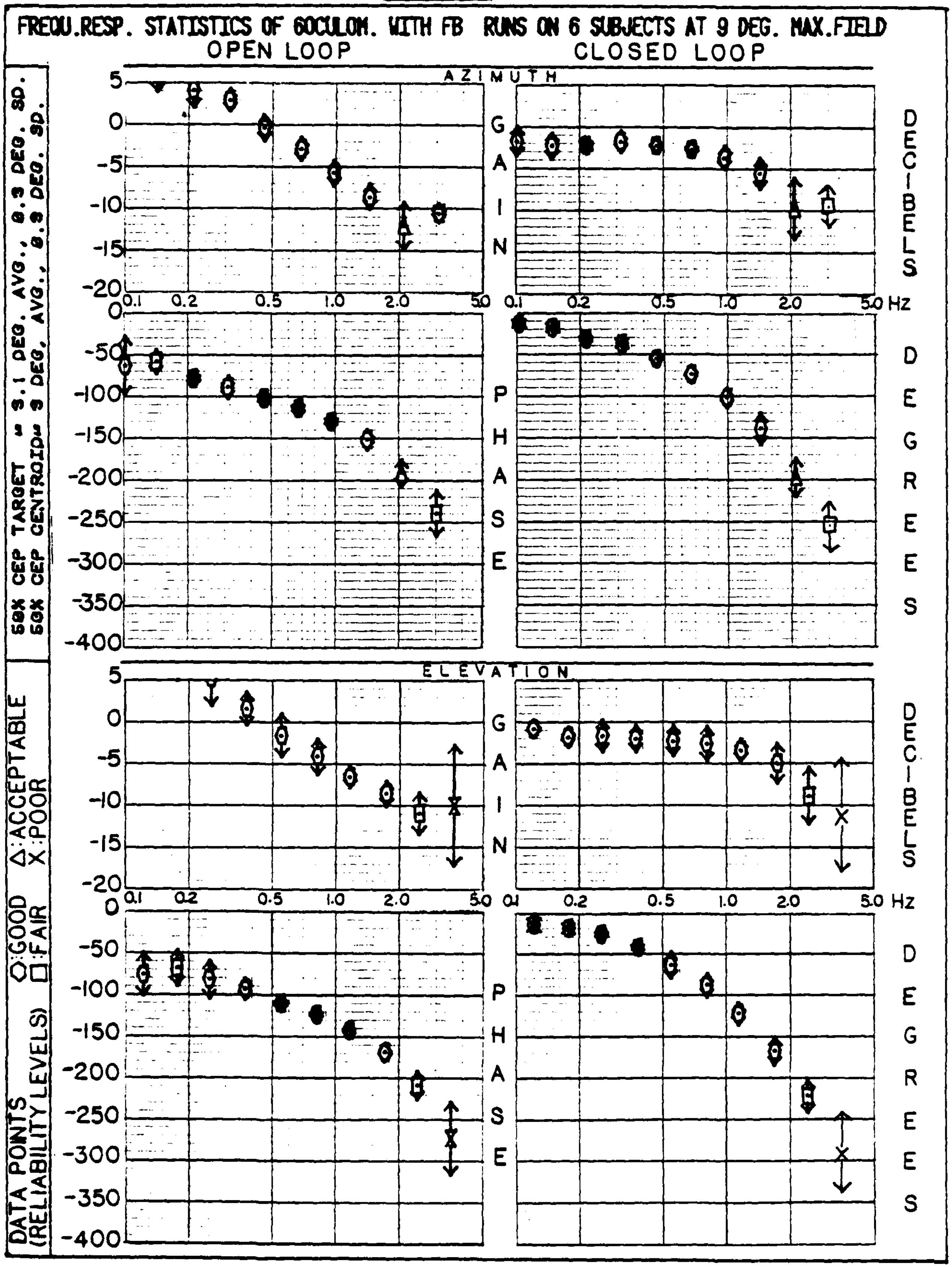
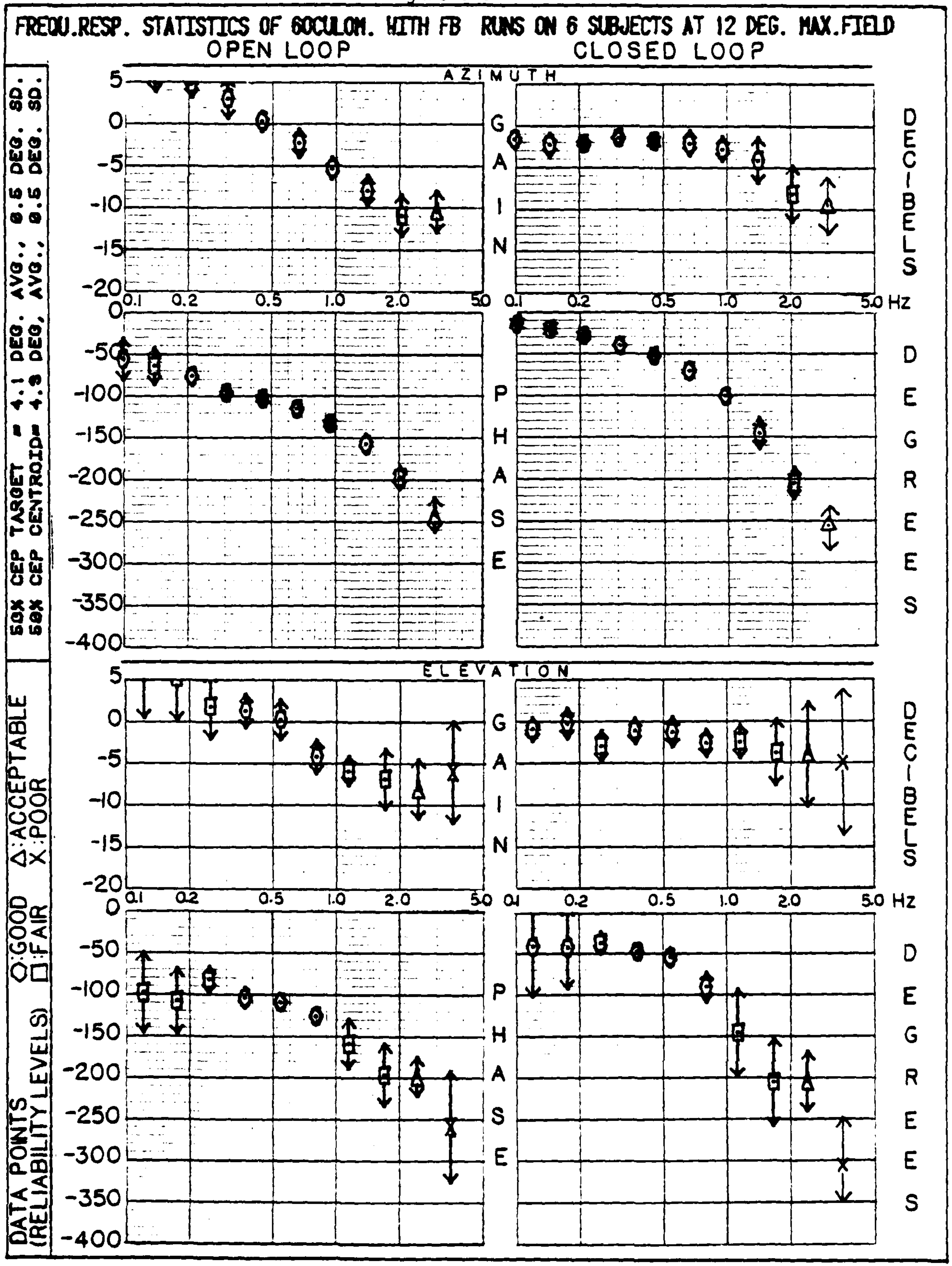

FREQU.RESP. STATISTICS OF 6OCULOM. WITH FB RUNS ON 6 SUBJECTS AT 9 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50X CEP TARGET = 3.1 DEG. AVG., 3.3 DEG. SD.
50X CEP CENTROID= 3 DEG. AVG., 3.3 DEG. SD.
△:ACCEPTABLE
X:POOR
○:GOOD
□:FAIR
DATA POINTS
(RELIABILITY LEVELS)

Figure 6-9


FREQU.RESP. STATISTICS OF 6OCULOM. WITH FB RUNS ON 6 SUBJECTS AT 12 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
SGX CEP TARGET = 4.1 DEG, AVG., 6.5 DEG. SD.
SGX CEP CENTROID= 4.3 DEG, AVG., 6.5 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
○:GOOD □:FAIR
△:ACCEPTABLE X:POOR

7. DESCRIBING FUNCTION MODELS

From examination of the closed-loop frequency response results presented in Figures 6-1 to 6-9, the following linear models for the (closed-loop) transfer function between target angle (input) and control angle (output) have been chosen:

$$G(s) = \frac{K(1 - s/A)e^{-sT}}{(1 + s/B)(1 + s/C)} \quad \text{for EOG tracking} \qquad (7\text{-}1)$$

$$G(s) = \frac{K\,e^{-sT}}{(1 + s/A)} \quad \text{for oculometer tracking} \qquad (7\text{-}2)$$

The parameter identification was performed from the averaged describing functions presented in Figures 6-1 to 6-9. They represent a total of 69 EOG runs and 36 oculometer runs on Subjects 3 through 14, all with forcing functions of 0.8 Hertz bandwidth, averaged in appropriate groups.

The results are presented in Tables 7-1 to 7-3. They are also presented in Figures 7-1(a) to 7-9(b) which show plots of the frequency responses of the models, together with the averaged measured frequency response points and their standard deviation ranges. Note that in all cases, the model response lies well within the standard deviation range of the measured data.

The parameter identification was carried out by means of a Gauss-Newton nonlinear least-square fit program. A two-step approach was used to first identify the parameters K, A, B, C (for the EOG model); or K, A (for the oculometer model) to fit the gain function and then to obtain the time-delay T from the phase function. The minimized root-mean-square difference between (average) measured and model data

are included in Tables 7-1 to 7-3, in a form suitable to serve as a measure of quality of the fit. They are presented, as "$\hat{\sigma}_{fit}$ ", both with respect to gain and phase.

TABLE 7-1: SUMMARY OF MODEL PARAMETERS

E O G Closed Loop Tracking Model: $G(s) = \frac{(1 - s/A)\,Ke^{-sT}}{(1 + s/B)(1 + s/C)}$

Maximum Field (degrees)	AZIMUTH					ELEVATION					No. of Subjects	No. of Runs
	K	A	B	C	T	K	A	B	C	T		
6	0.658	3.604	7.044	7.990	0.131	0.617	1.872	2.602	15.61	0.112	12	24
9	0.553	3.384	8.033	7.634	0.134	0.598	1.746	2.542	11.90	0.102	12	24
12	0.512	2.427	6.276	6.874	0.108	0.563	2.002	3.628	8.750	0.105	12	21

Fit Based on		Azimuth GAIN	Azimuth PHASE	Elevation GAIN	Elevation PHASE
ζ_{fit} for*	6°	-25.34 dB	12.24°	-25.98 dB	13.51°
	9°	-26.00 dB	7.95°	-26.00 dB	15.00°
	12°	-30.47 dB	14.05°	-26.54 dB	15.26°

$$
{}^{*}\zeta_{fit} = \begin{cases} 20 \log \sqrt{\frac{1}{10}\sum_{i=1}^{10} [G_i - G_{i,model}(f_i, \text{Parameters})]^2} & \text{[decibels]} \\ \sqrt{\frac{1}{10}\sum_{i=1}^{10} [P_i - P_{i,model}(f_i, \text{Parameters})]^2} & \text{[degrees]} \end{cases}
$$

Where: G_i and P_i are averaged gain and phase respectivly; obtained from measured data at frequency f_i.

$G_{i,model}$ and $P_{i,model}$ are gain and phase of model for frequency f_i.

TABLE 7-2: **SUMMARY OF MODEL PARAMETERS**

Oculometer Without Feedback Closed Loop Tracking Model: $G(s) = \dfrac{Ke^{-sT}}{(1 + s/A)}$

Maximum Field (degrees)	AZIMUTH			ELEVATION			No. of Subjects	No. of Runs
	K	A	T	K	A	T		
6	0.793	9.928	0.191	0.864	10.501	0.206	6	6
9	0.823	11.076	0.184	0.894	11.334	0.194	6	6
12	0.848	12.115	0.118	0.903	13.279	0.193	6	6

Fit Based on		AZIMUTH GAIN	AZIMUTH PHASE	ELEVATION GAIN	ELEVATION PHASE
δ_{fit} for*	6°	-29.03 dB	4.63°	-23.20 dB	6.74°
	9°	-35.22 dB	3.43°	-28.38 dB	5.40°
	12°	-34.78 dB	1.77°	-31.83 dB	2.01°

$$\left\{ \begin{array}{ll} 20 \log \sqrt{\frac{1}{10}\sum_{i=1}^{10}[G_i - G_{i,model}(f_i, \text{Parameters})]^2} & \text{[decibels]} \\ \sqrt{\frac{1}{10}\sum_{i=1}^{10}[P_i - P_{i,model}(f_i, \text{Parameters})]^2} & \text{[degrees]} \end{array} \right.$$

Where: G_i and P_i are averaged gain and phase respectivly; obtained from measured data at frequency f_i.

$G_{i,model}$ and $P_{i,model}$ are gain and phase of model for frequency f_i.

TABLE 7-3: SUMMARY OF MODEL PARAMETERS

Oculometer With Feedback Closed Loop Tracking Model: $G(s) = \dfrac{Ke^{-sT}}{(1 + s/A)}$

Maximum Field (degrees)	AZIMUTH K	AZIMUTH A	AZIMUTH T	ELEVATION K	ELEVATION A	ELEVATION T	No. of Subjects	No. of Runs
6	0.856	6.832	0.166	0.847	6.705	0.161	6	6
9	0.820	7.381	0.175	0.848	8.527	0.177	6	6
12	0.843	8.617	0.186	0.853	17.606	0.208	6	6

Fit Based on		AZIMUTH GAIN	AZIMUTH PHASE	ELEVATION GAIN	ELEVATION PHASE
ζ_{fit} for*	6^{o}	-31.24 dB	6.24^{o}	-27.46 dB	11.78^{o}
	9^{o}	-28.88 dB	2.96^{o}	-29.83 dB	4.56^{o}
	12^{o}	-27.88 dB	4.26^{o}	-22.70 dB	24.81^{o}

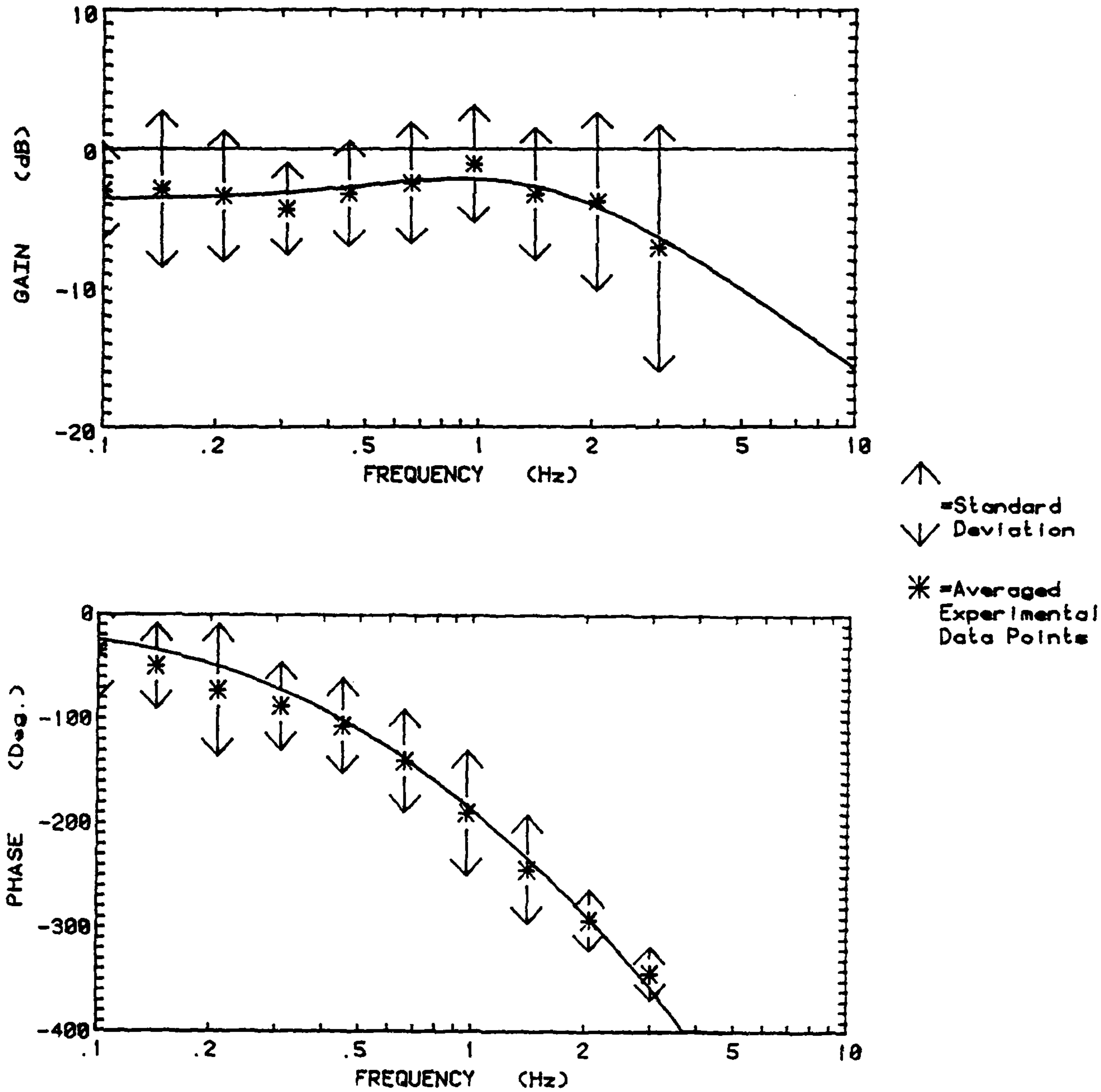
$$^{*}\zeta_{fit} = \begin{cases} 20 \log \sqrt{\frac{1}{10}\sum_{i=1}^{10}[G_i - G_{i,model}(f_i, Parameters)]^2} & [decibels] \\ \sqrt{\frac{1}{10}\sum_{i=1}^{10}[P_i - P_{i,model}(f_i, Parameters)]^2} & [degrees] \end{cases}$$

Where: G_i and P_i are averaged gain and phase respectivly; obtained from measured data at frequency f_i.

$G_{i,model}$ and $P_{i,model}$ are gain and phase of model for frequency f_i.

Figure 7-1 (a)

E O G
AZIMUTH CLOSED LOOP
6 Deg. Maximum Field
For 12 Subjects, 24 Runs



FUNCTION:

$$G(s) = \frac{(1 - s/A)\, K e^{-sT}}{(1 + s/B)\,(1 + s/C)}$$

PARAMETERS:

K= 0.658
A= (0.574)2π= 3.604
B= (0.121)2π= 0.761
C= (0.127)2π= 0.798
T= 0.131

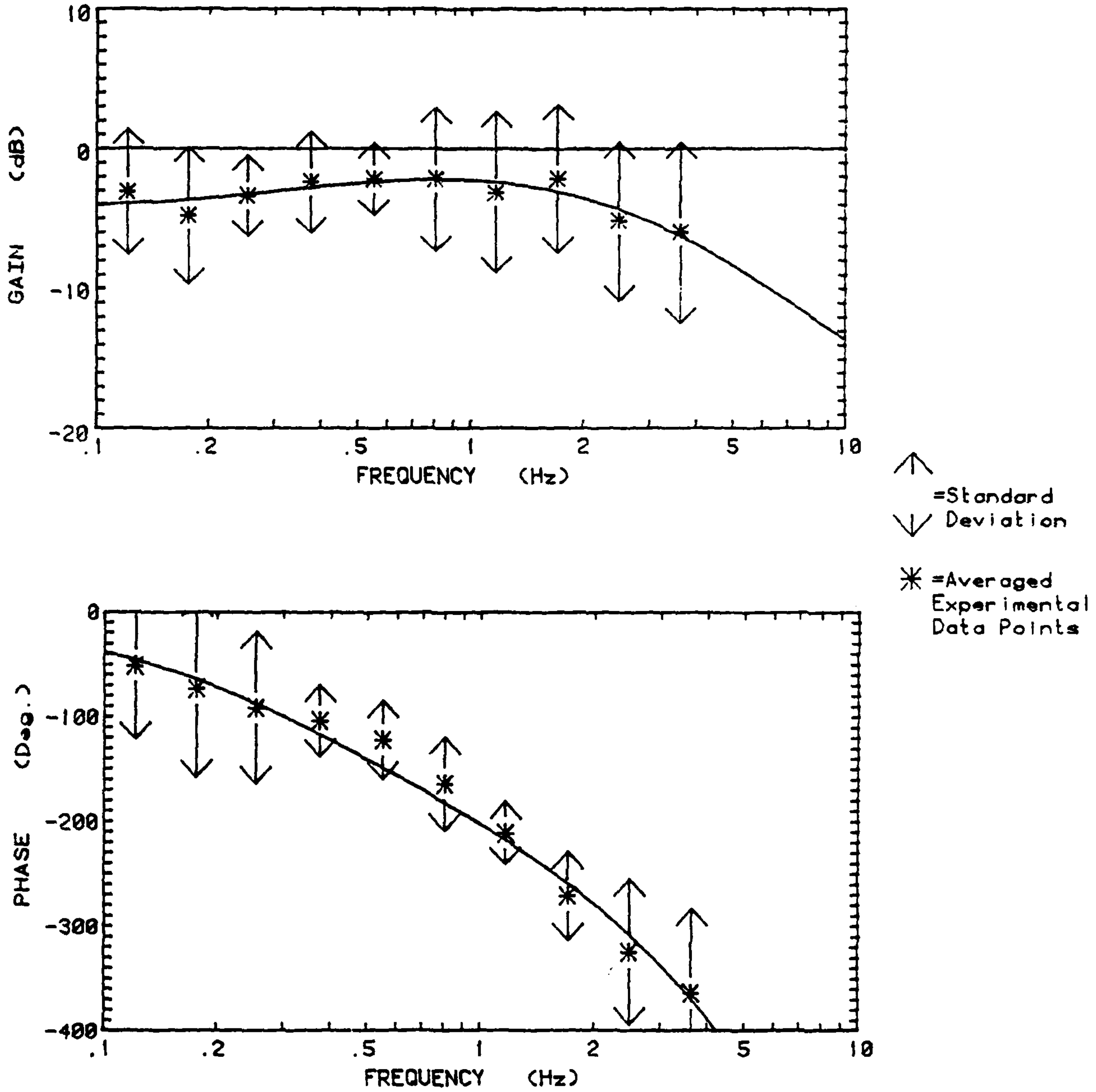
Figure 7-1 (b)

E O G

ELEVATION CLOSED LOOP

6 Deg. Maximum Field

For 12 Subjects, 24 Runs



FUNCTION:

$$G(s) = \frac{(1 - s/A)\,Ke^{-sT}}{(1 + s/B)\,(1 + s/C)}$$

PARAMETERS:

K= 0.617

A= (0.298)2π= 1.872

B= (0.414)2π= 2.602

C= (2.485)2π=15.614

T= 0.112

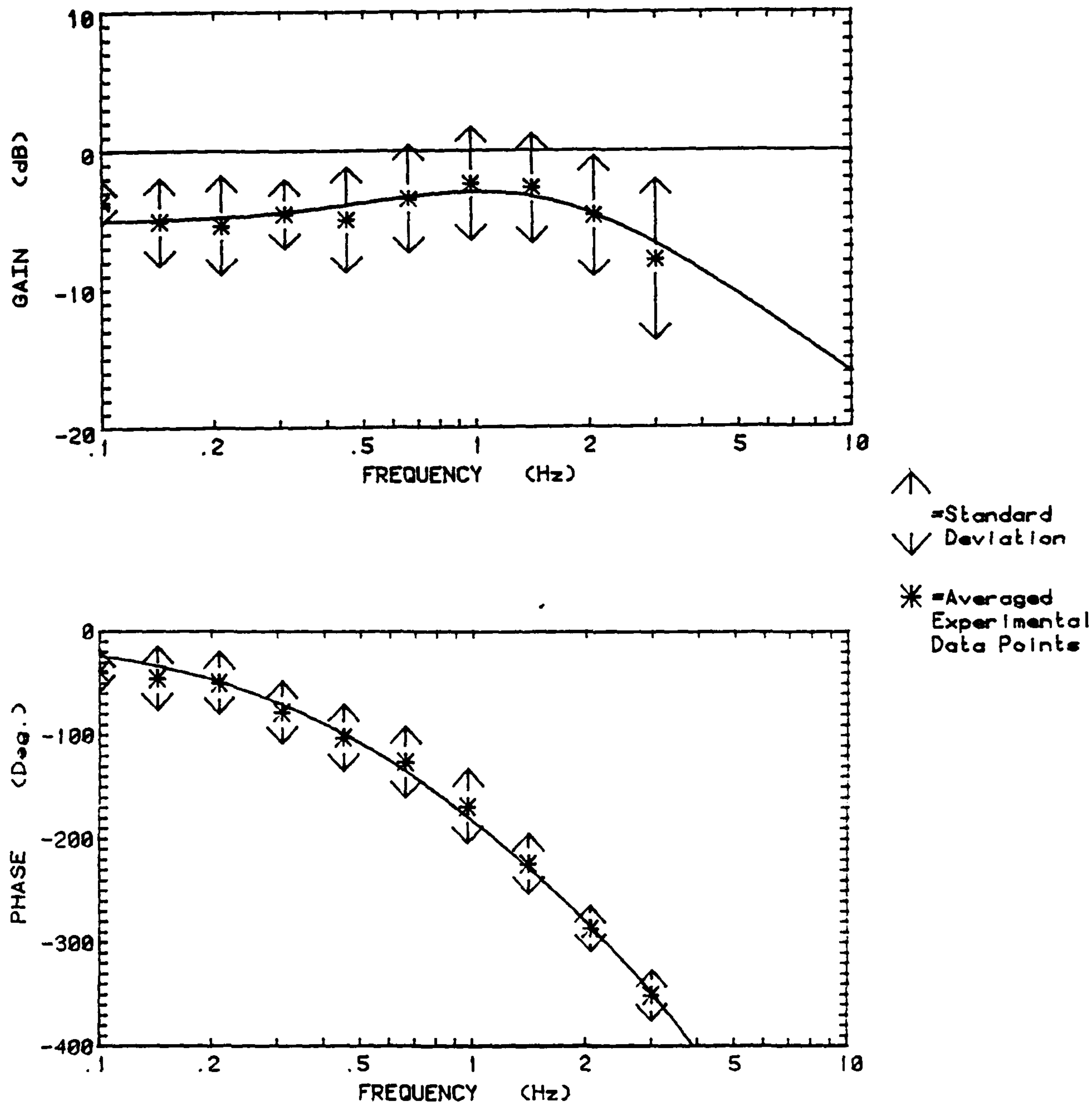
Figure 7-2 (a)

E O G

AZIMUTH CLOSED LOOP

9 Deg. Maximum Field

For 12 Subjects, 24 Runs



FUNCTION:

$$G(s) = \frac{(1 - s/A)\,Ke^{-sT}}{(1 + s/B)(1 + s/C)}$$

PARAMETERS:

K= 0.553

A= (0.539)2π= 3.384

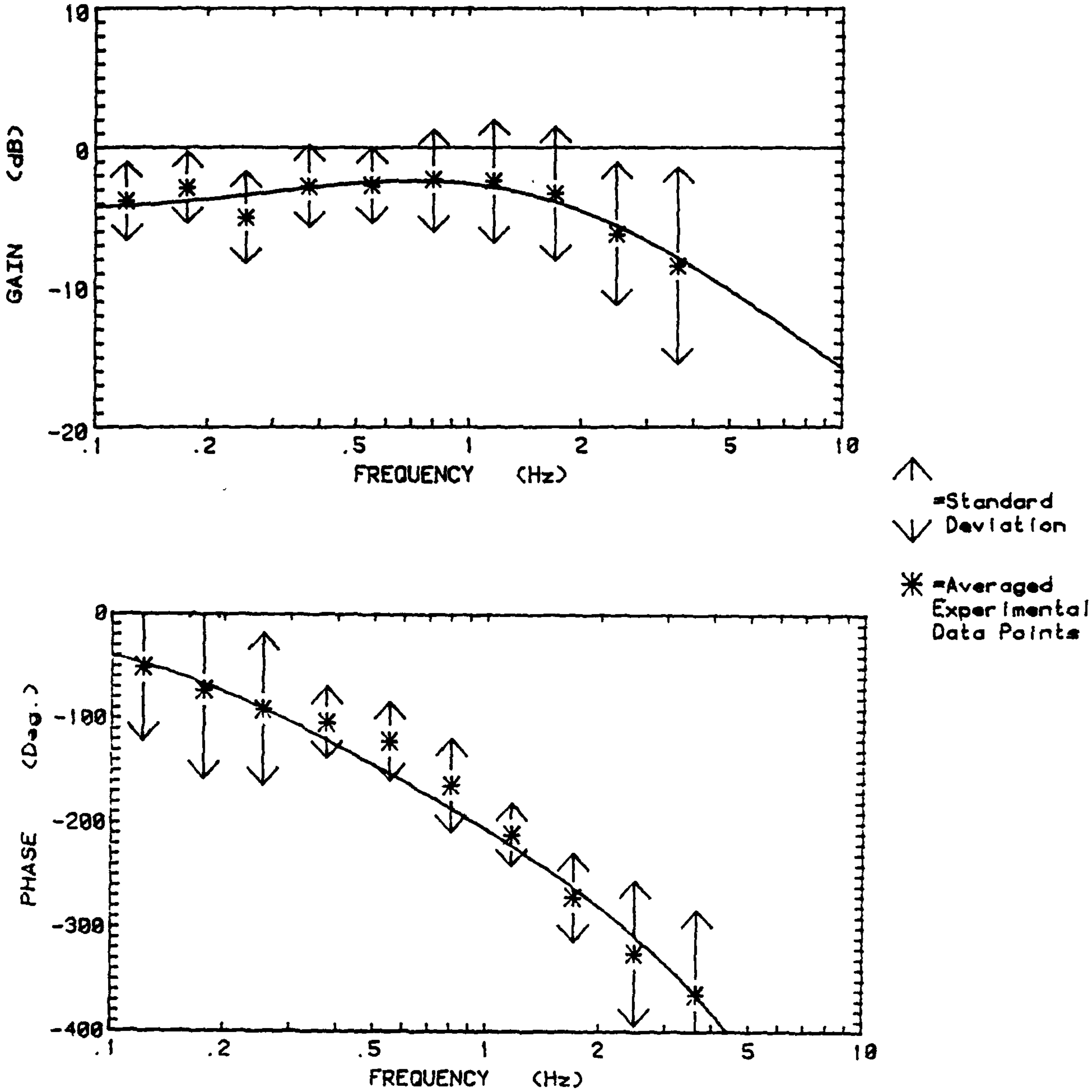
B= (1.279)2π= 8.033

C= (1.215)2π= 7.634

T= 0.124

Figure 7-2 (b)

E O G
ELEVATION CLOSED LOOP
9 Deg. Maximum Field
For 12 Subjects, 24 Runs



FUNCTION:

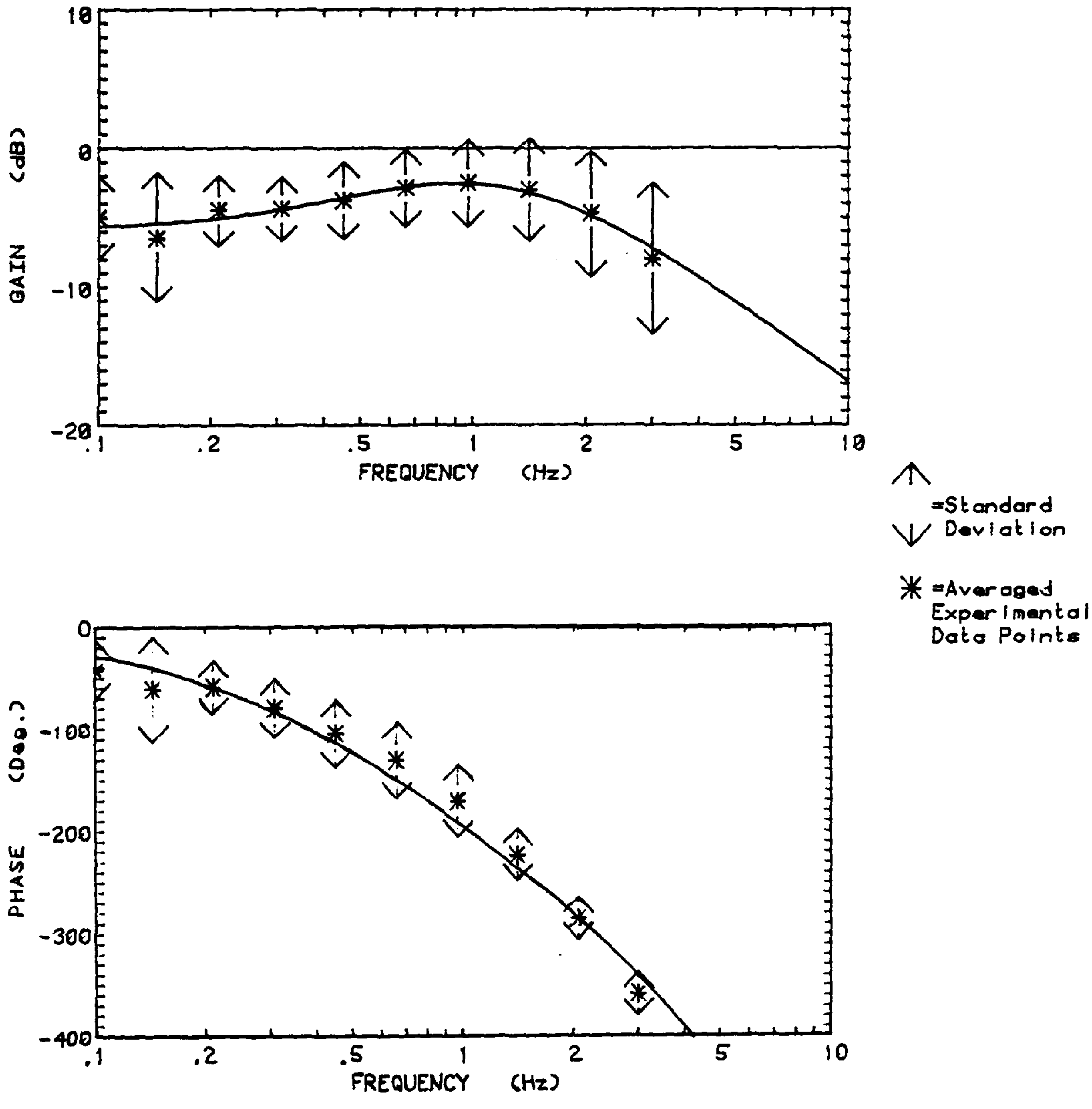
$$G(s) = \frac{(1 - s/A)\, Ke^{-sT}}{(1 + s/B)\,(1 + s/C)}$$

PARAMETERS:

K= 0.598
A= (0.278)2π= 1.746
B= (0.405)2π= 2.542
C= (1.894)2π=11.901
T= 0.102

Figure 7-3 (a)

E O G
AZIMUTH CLOSED LOOP
12 Deg. Maximum Field
For 12 Subjects, 21 Runs



FUNCTION:

$$G(s) = \frac{(1 - s/A)\, Ke^{-sT}}{(1 + s/B)\,(1 + s/C)}$$

PARAMETERS:

K= 0.512
A= (0.386)2π = 2.427
B= (0.999)2π = 6.276
C= (1.094)2π = 6.874
T= 0.108

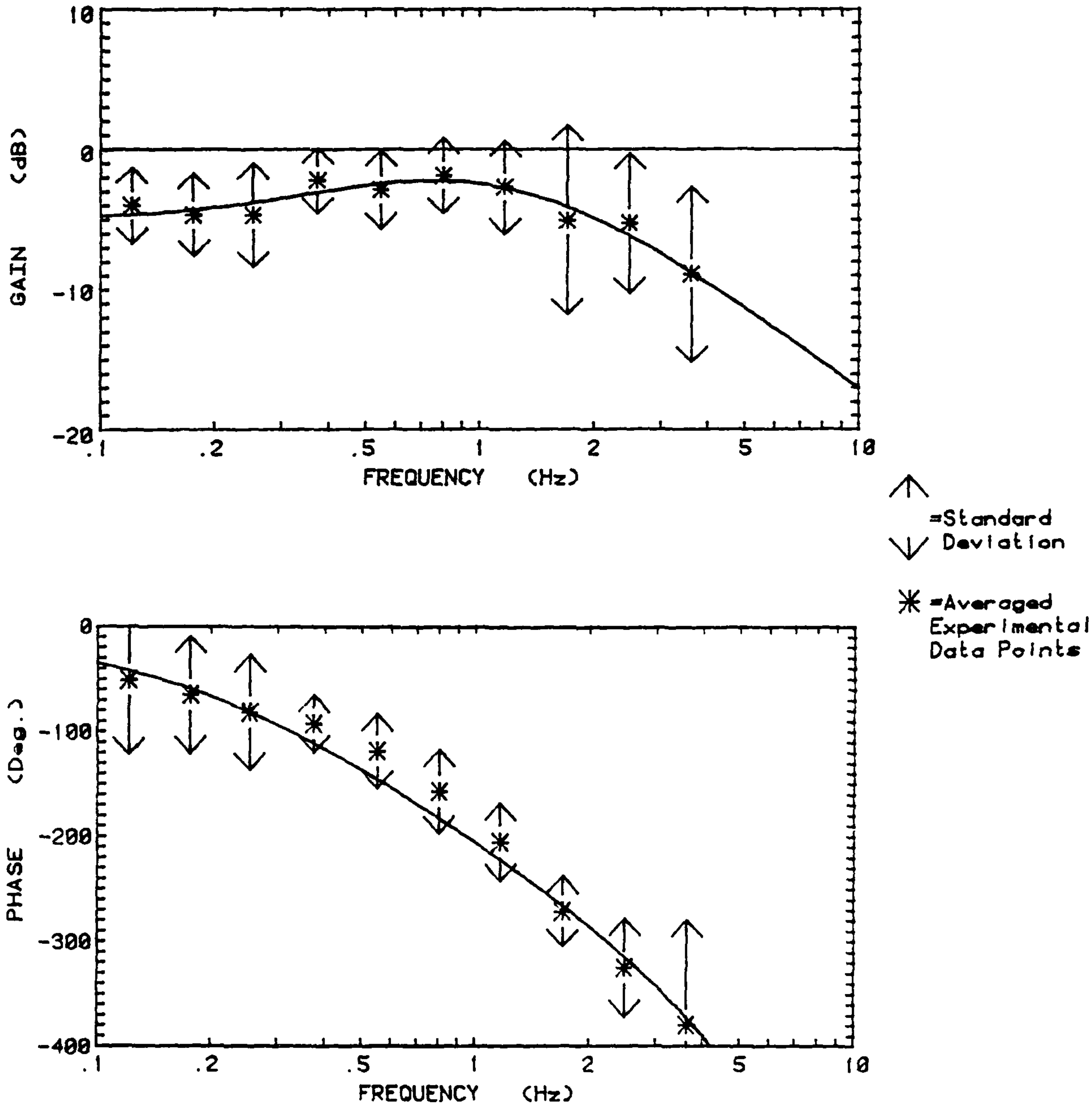
Figure 7-3 (b)

E O G

ELEVATION CLOSED LOOP

12 Deg. Maximum Field

For 12 Subjects, 21 Runs



FUNCTION:

$$G(s) = \frac{(1 - s/A)\, Ke^{-sT}}{(1 + s/B)\,(1 + s/C)}$$

PARAMETERS:

K= 0.563

A= (0.319)2π= 2.002

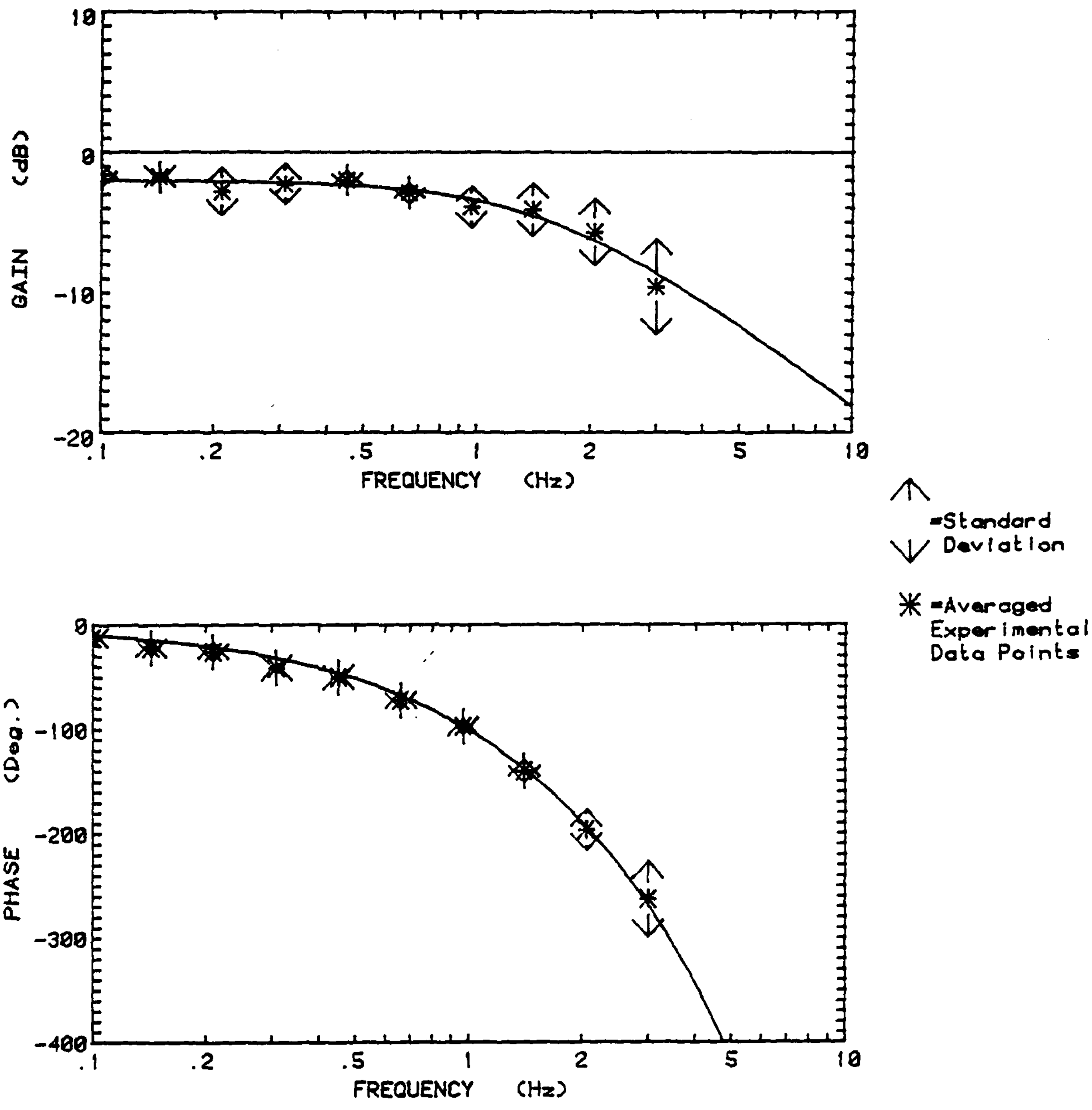
B= (0.577)2π= 3.628

C= (1.393)2π= 8.750

T= 0.105

Figure 7-4 (a)

OCCULOMETER WITHOUT FEEDBACK
AZIMUTH CLOSED LOOP
6 Deg. Maximum Field
For 6 Subjects, 6 Runs



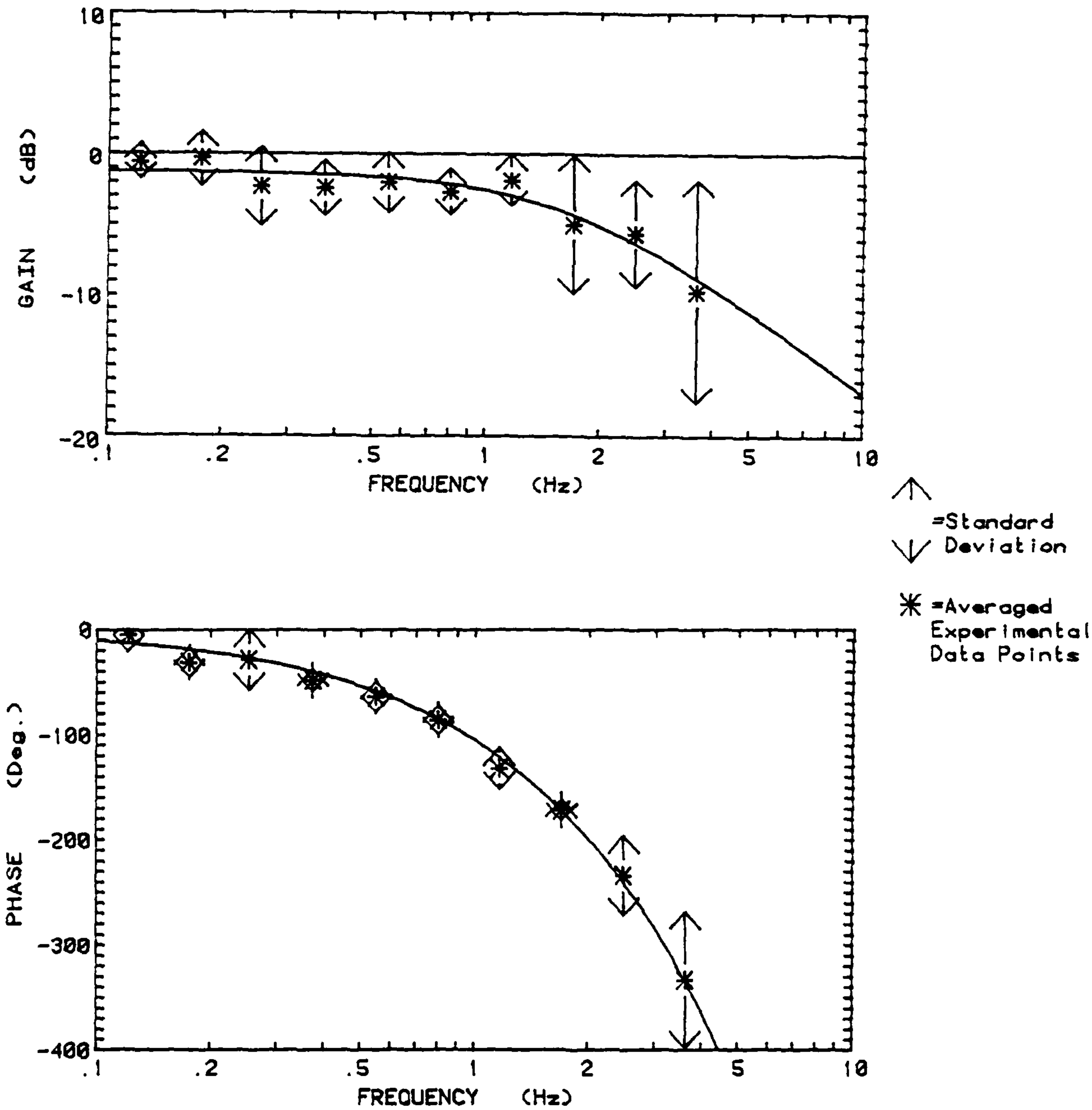
FUNCTION:

$$G(s) = \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.793
A= (1.580)2π= 9.928
T= 0.191

Figure 7-4 (b)
OCCULOMETER WITHOUT FEEDBACK
ELEVATION CLOSED LOOP
6 Deg. Maximum Field
For 6 Subjects, 6 Runs



FUNCTION:

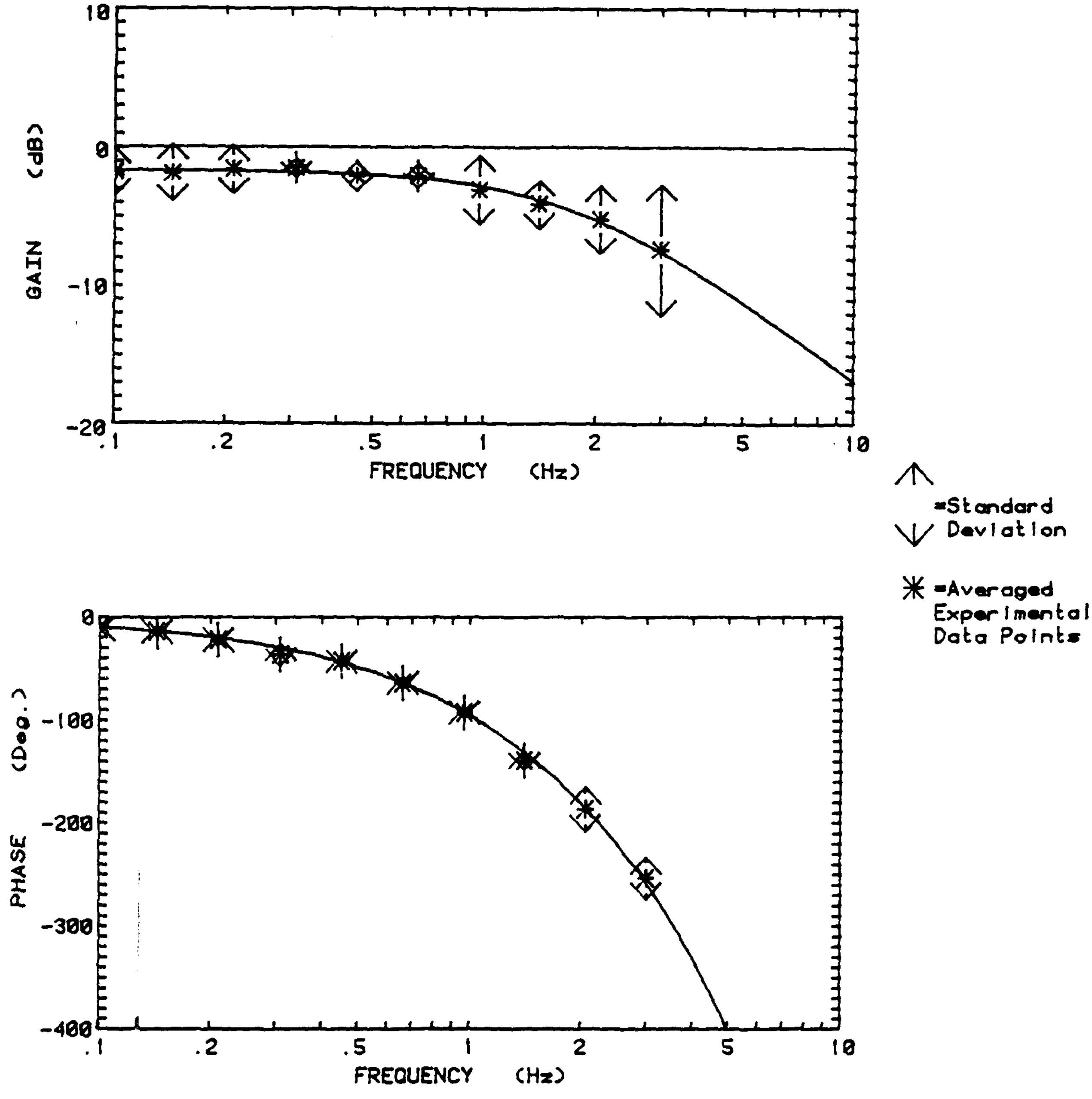
$$G(s) = \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.864
A= (1.671)2π=10.501
T= 0.206

Figure 7-5 (a)

OCCULOMETER WITHOUT FEEDBACK
AZIMUTH CLOSED LOOP
9 Deg. Maximum Field
For 6 Subjects, 6 Runs



FUNCTION:

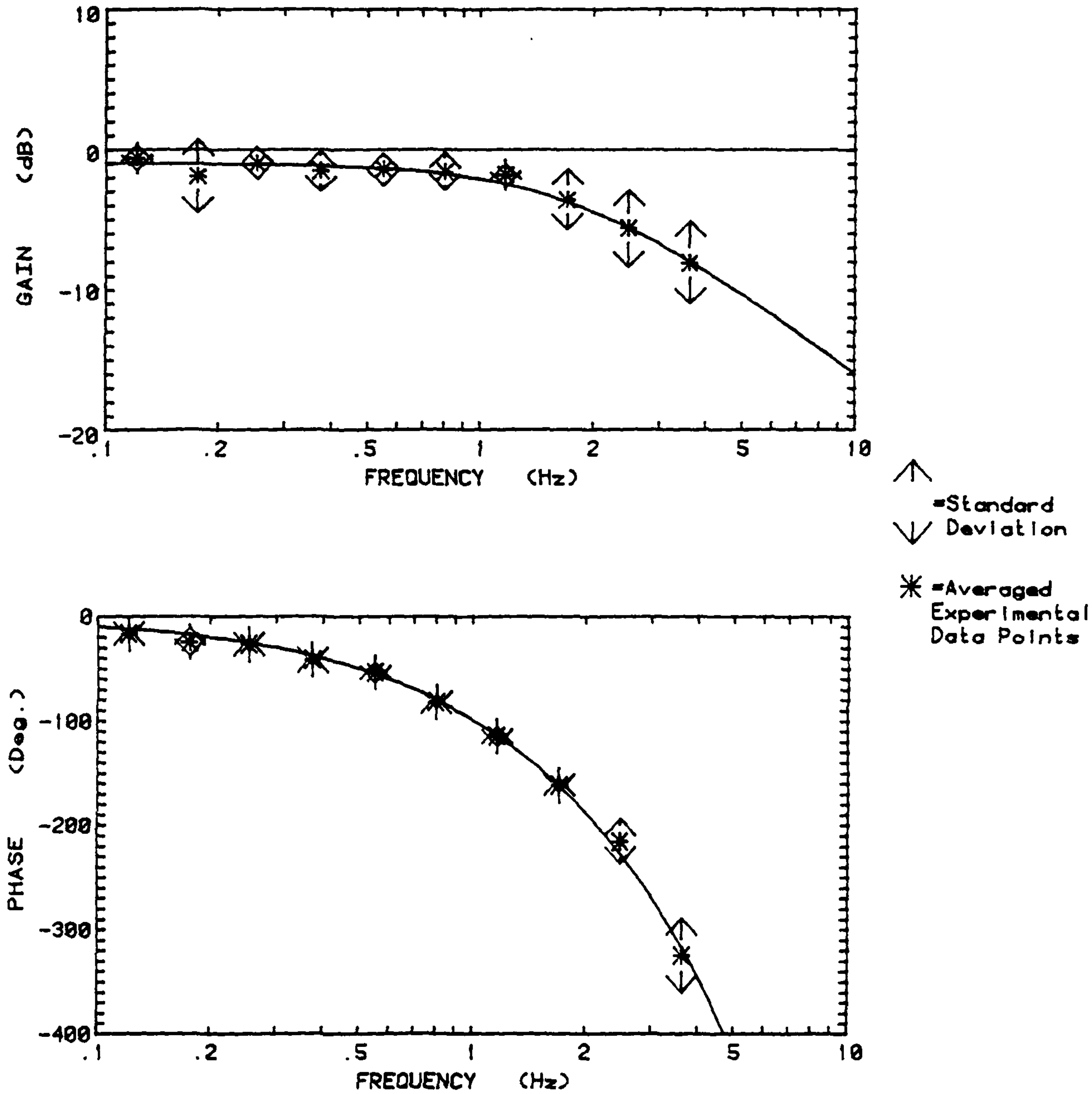
$$G(s) = \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.823
A= (1.763)2π=11.076
T= 0.184

Figure 7-5 (b)

OCCULOMETER WITHOUT FEEDBACK
ELEVATION CLOSED LOOP
9 Deg. Maximum Field
For 6 Subjects, 6 Runs



FUNCTION:

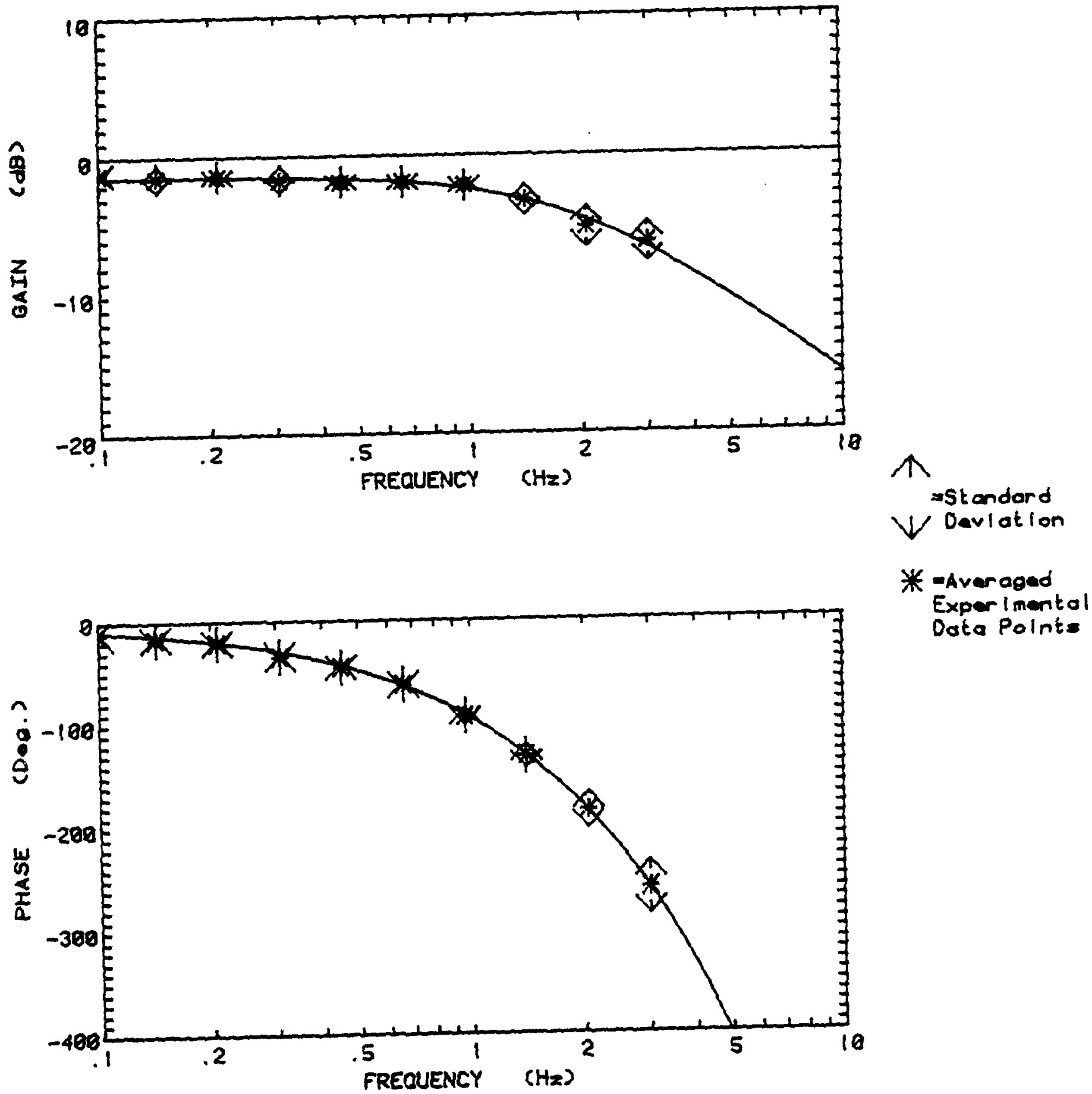
$$G(s) = \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.894
A= (1.804)2π=11.334
T= 0.194

Figure 7-6 (a)

OCCULOMETER WITHOUT FEEDBACK
AZIMUTH CLOSED LOOP
12 Deg. Maximum Field
For 6 Subjects, 6 Runs



FUNCTION:

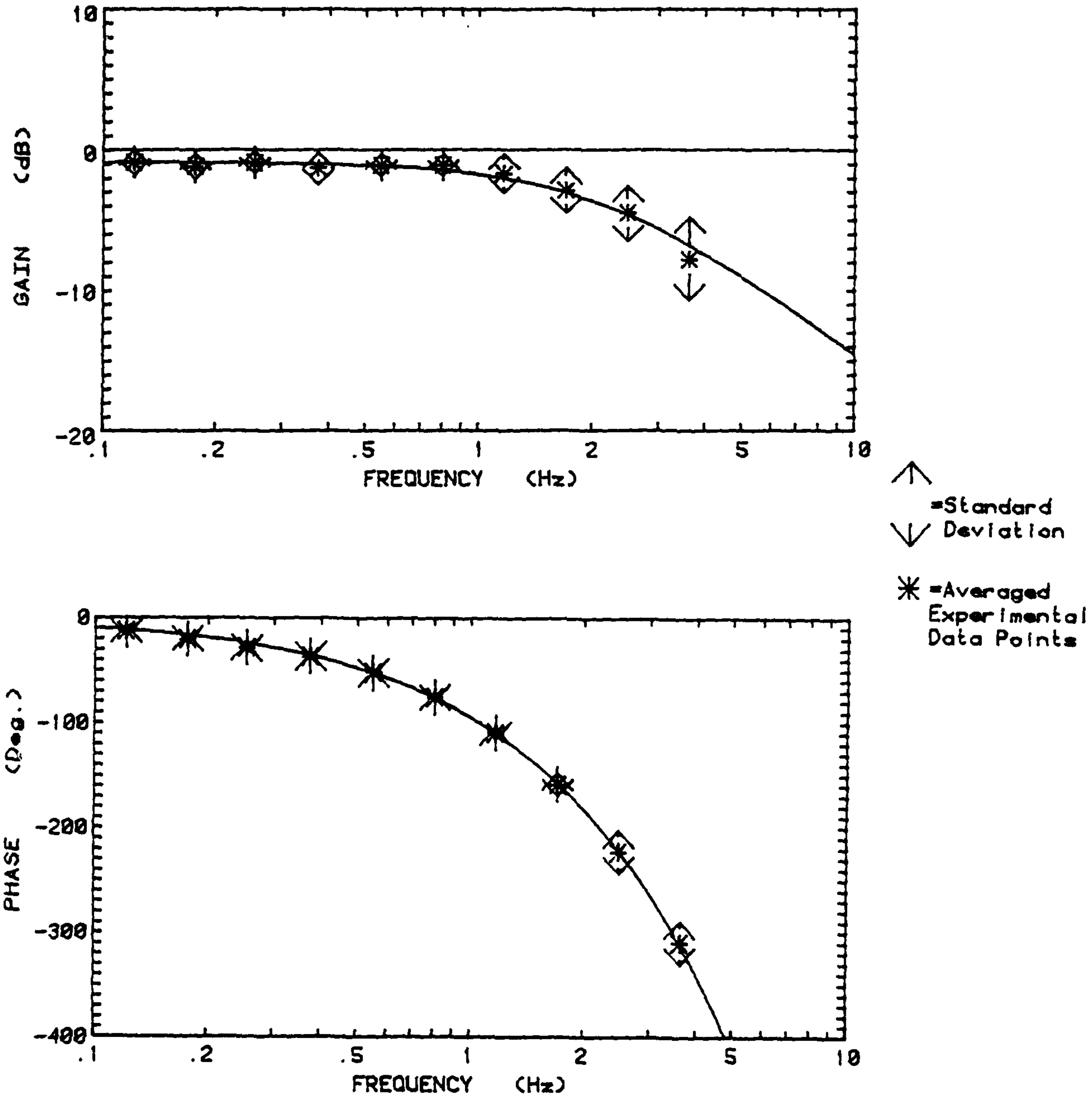
$$G(s) = \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.848
A= (1.928)2π=12.115
T= 0.188

Figure 7-6 (b)

OCCULOMETER WITHOUT FEEDBACK
ELEVATION CLOSED LOOP
12 Deg. Maximum Field
For 6 Subjects, 6 Runs



FUNCTION:

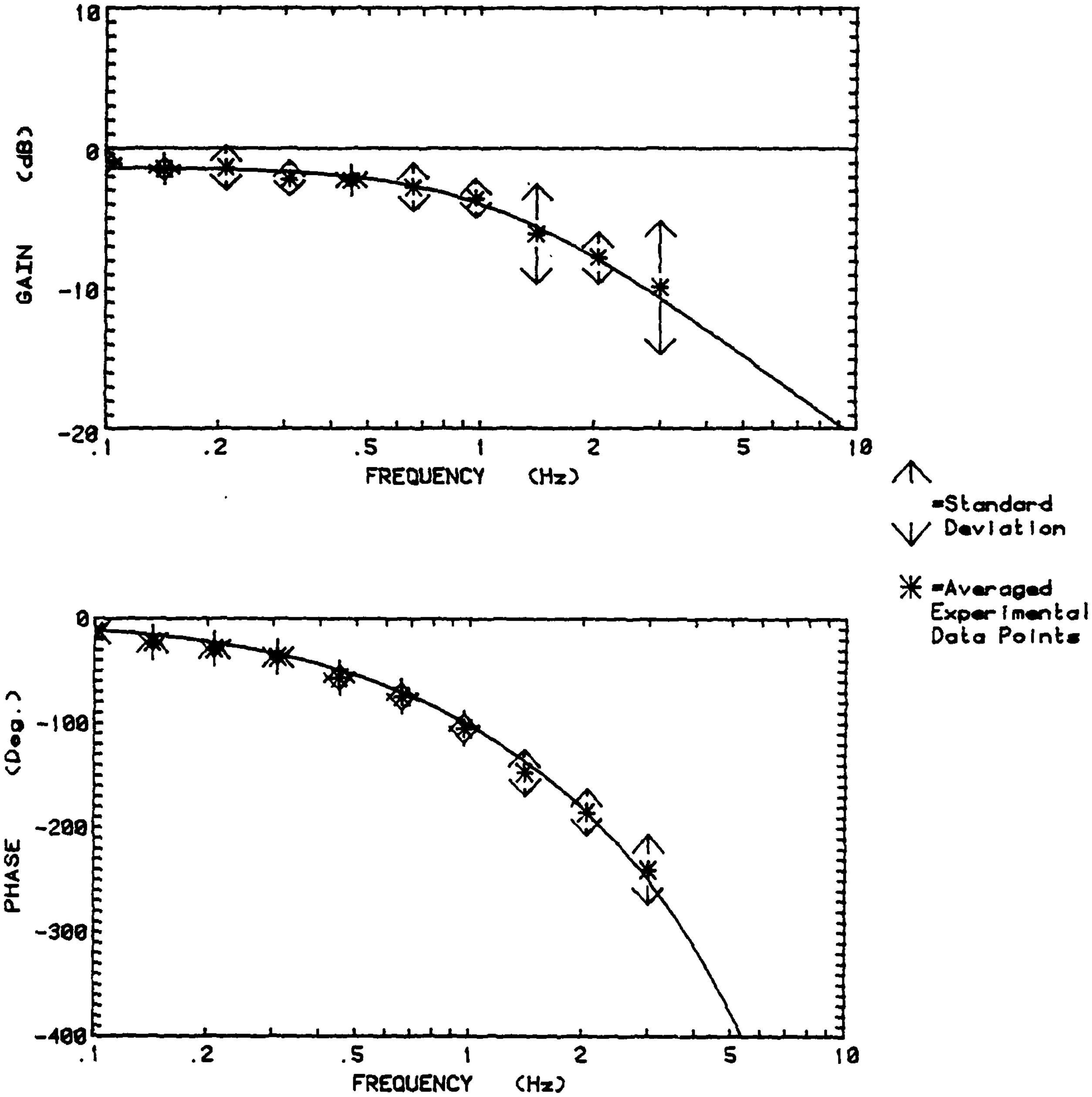
$$G(s) = \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.903
A= (2.113)2π=13.279
T= 0.193

Figure 7-7 (a)

OCCULOMETER WITH FEEDBACK
AZIMUTH CLOSED LOOP
6 Deg. Maximum Field
For 6 Subjects, 6 Runs



FUNCTION:

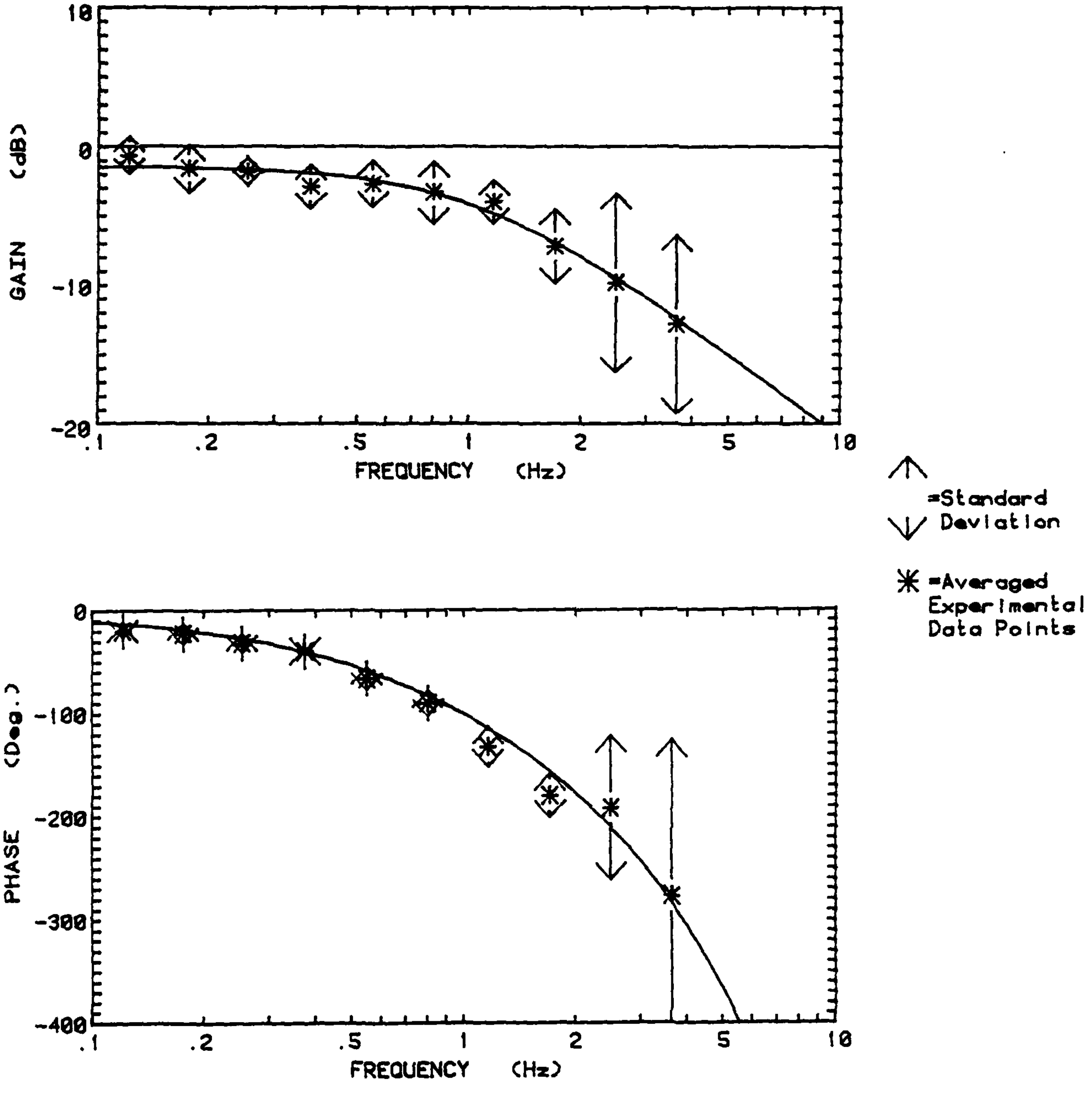
$$G(s) = \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.856
A= (1.087)2π= 6.832
T= 0.166

Figure 7-7 (b)

OCCULOMETER WITH FEEDBACK
ELEVATION CLOSED LOOP
6 Deg. Maximum Field
For 6 Subjects, 6 Runs



FUNCTION:

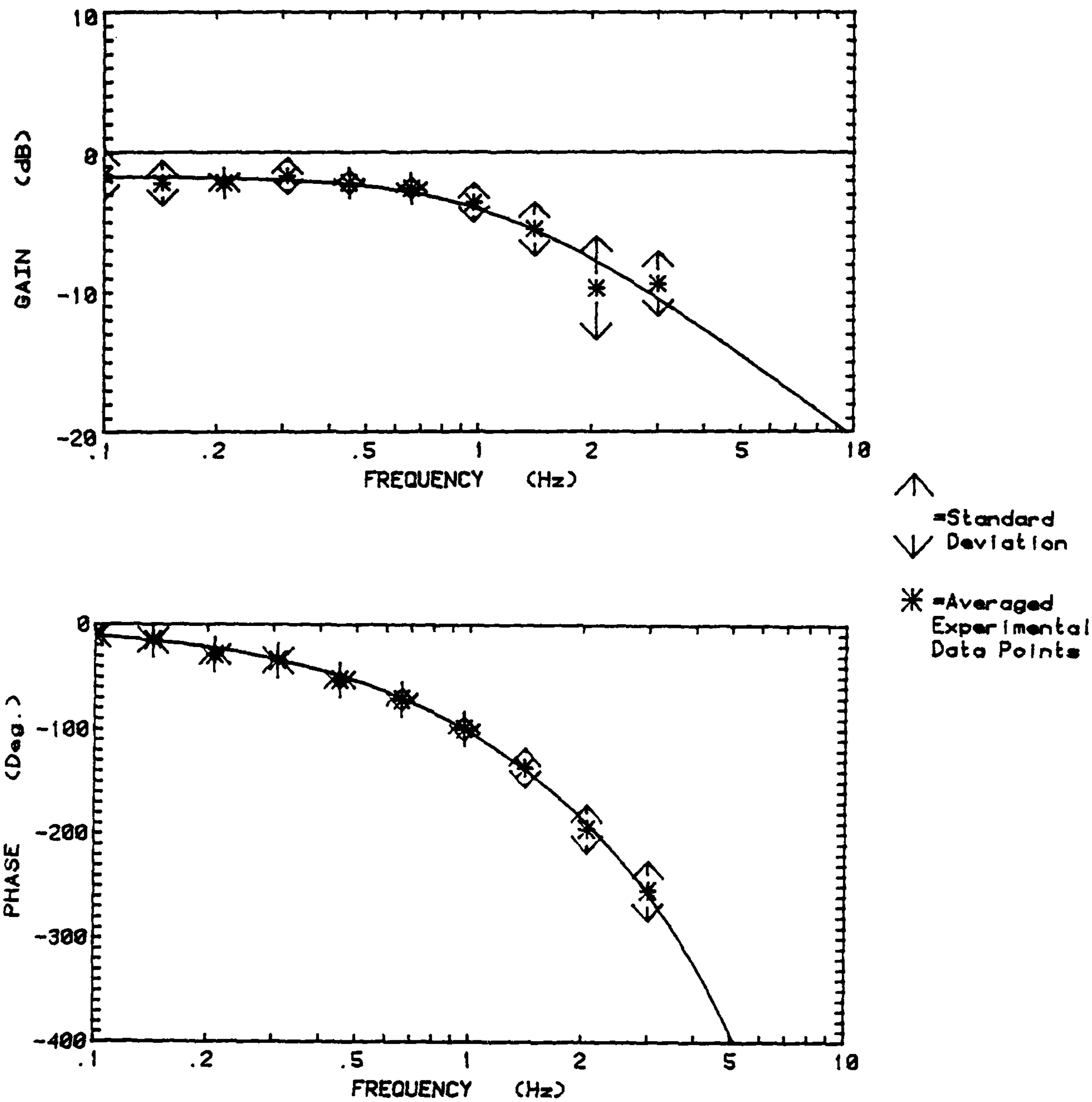
$$G(s) = \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.847
A= (1.067)2π= 6.705
T= 0.161

Figure 7-8 (a)

OCCULOMETER WITH FEEDBACK
AZIMUTH CLOSED LOOP
9 Deg. Maximum Field
For 6 Subjects, 6 Runs



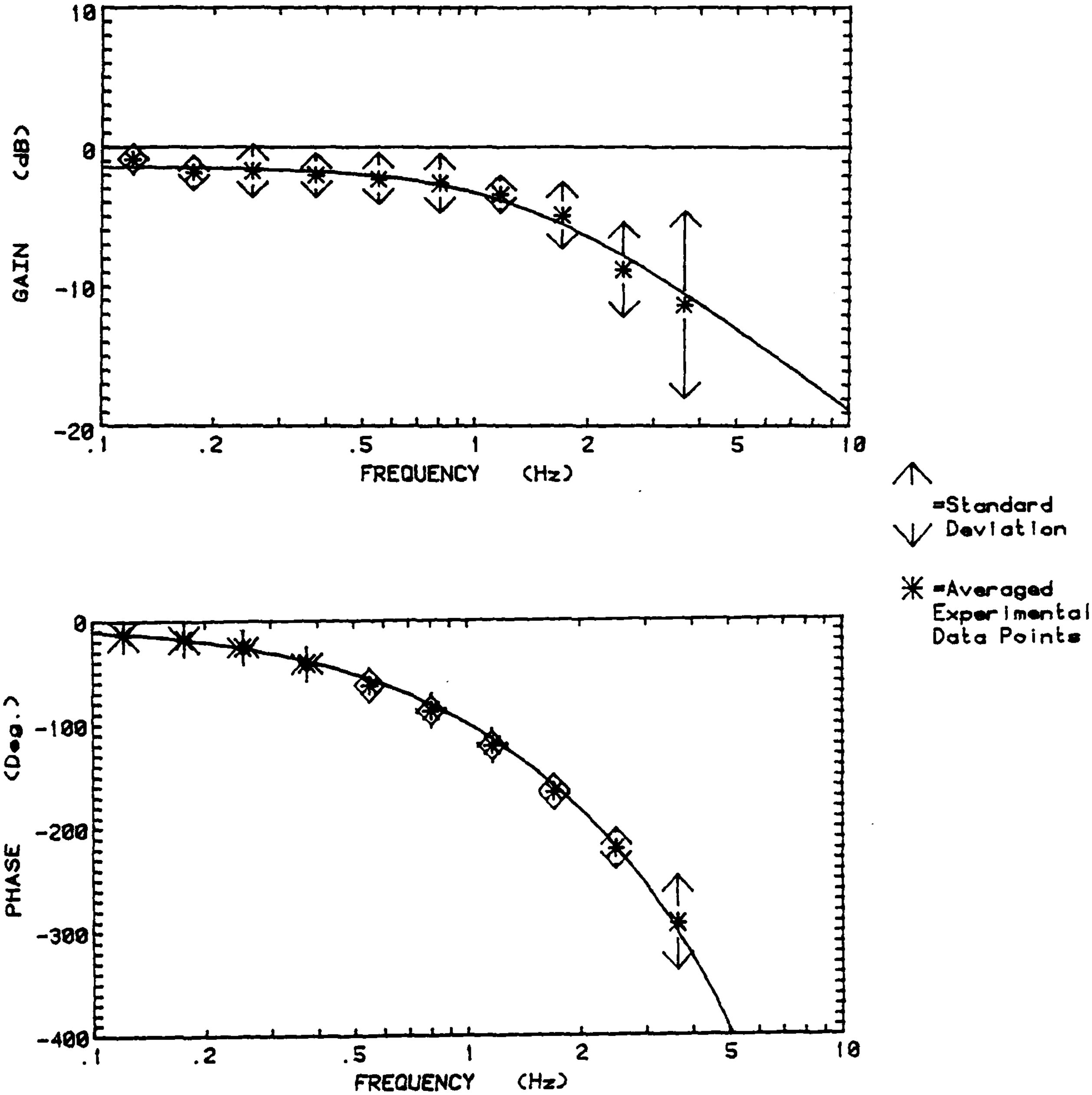
FUNCTION:

$$G(s) = \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.820
A= (1.175)2π= 7.381
T= 0.175

Figure 7-8 (b)
OCCULOMETER WITH FEEDBACK
ELEVATION CLOSED LOOP
9 Deg. Maximum Field
For 6 Subjects, 6 Runs



FUNCTION:

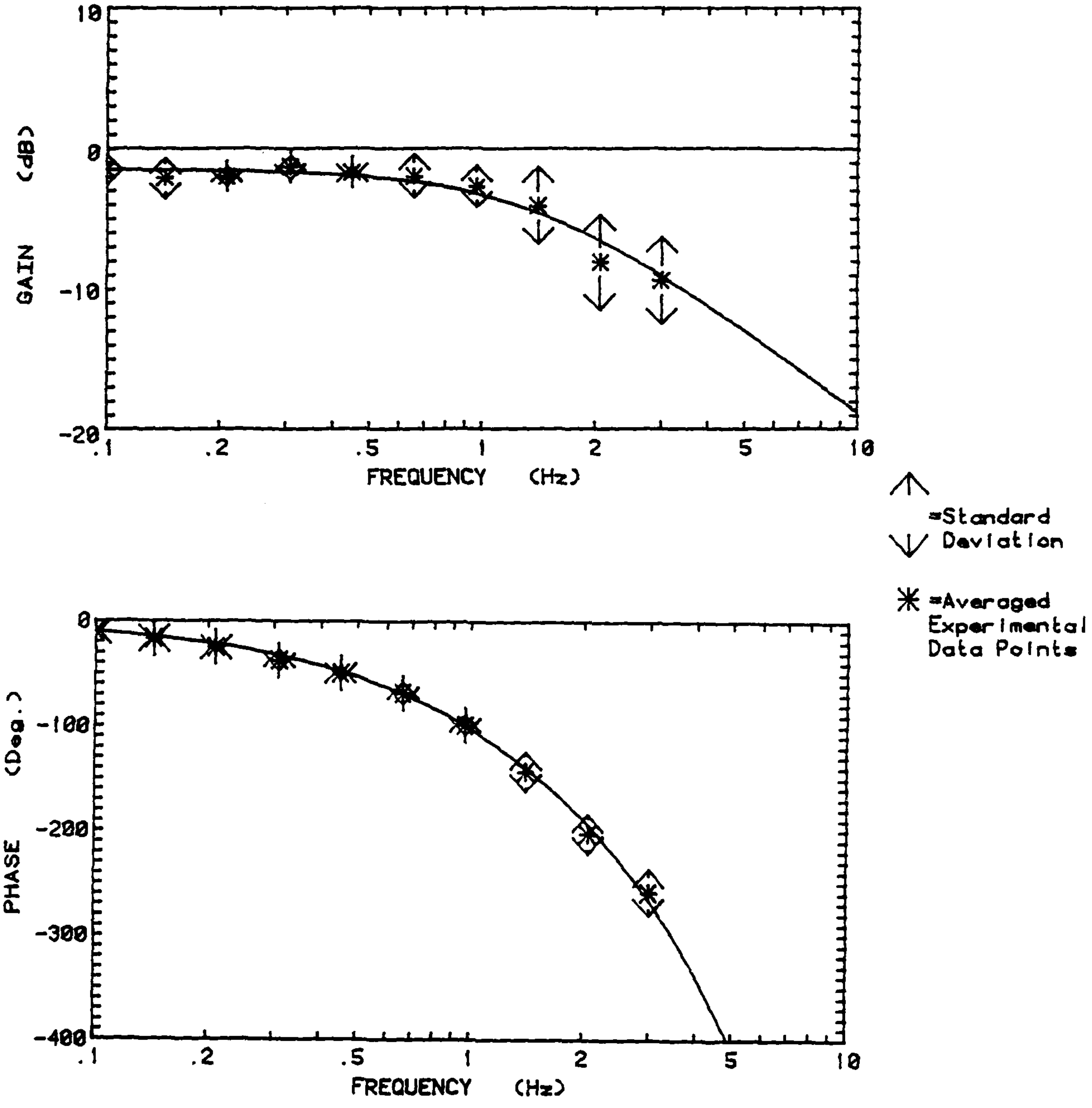
$$G(s)=\frac{Ke^{-sT}}{(1+s/A)}$$

PARAMETERS:

K= 0.848
A= (1.357)2π= 8.527
T= 0.177

Figure 7-9 (a)

OCCULOMETER WITH FEEDBACK
AZIMUTH CLOSED LOOP
12 Deg. Maximum Field
For 6 Subjects, 6 Runs



FUNCTION:

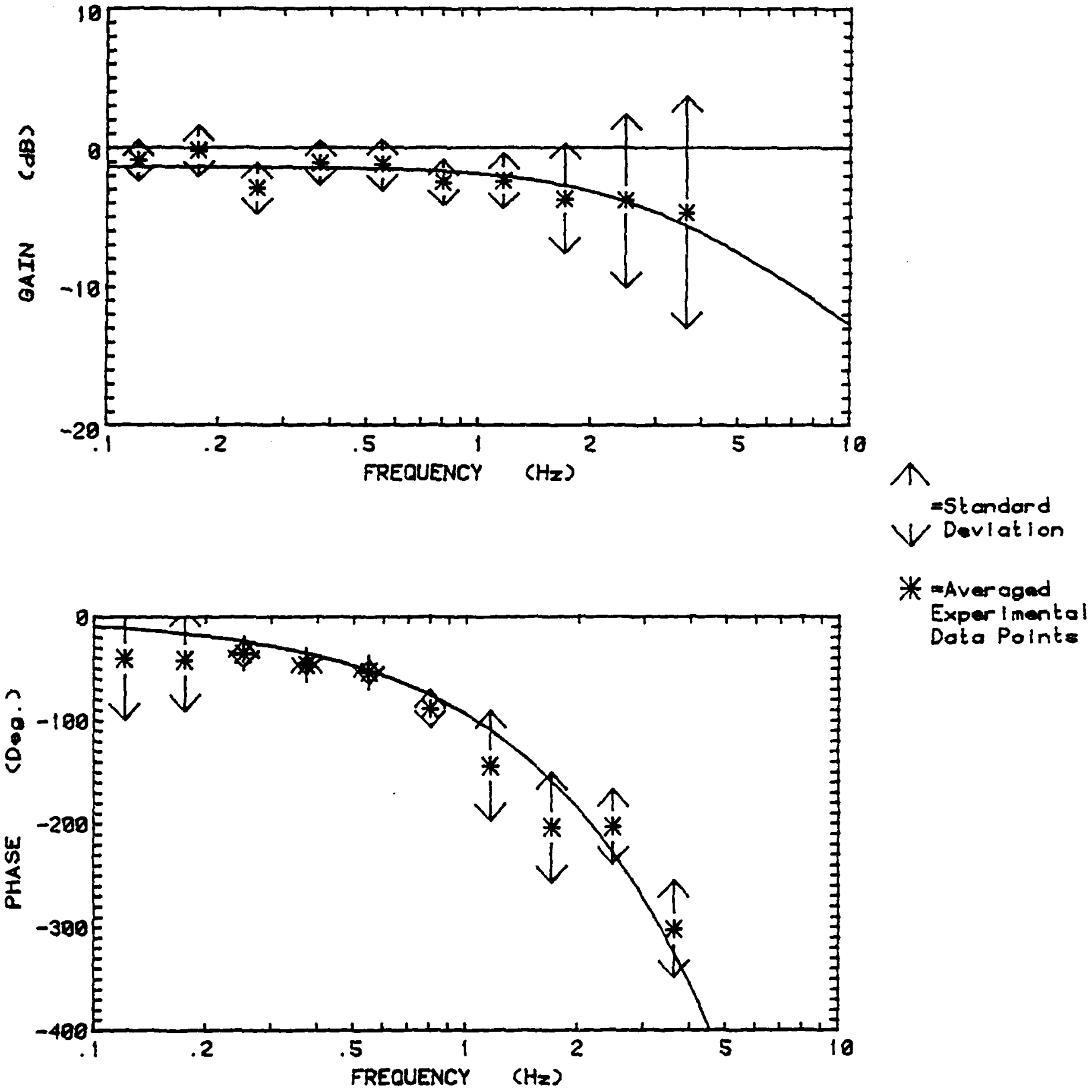
$$G(s) = \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.843
A= (1.371)2π= 8.617
T= 0.186

Figure 7-9 (b)

OCCULOMETER WITH FEEDBACK
ELEVATION CLOSED LOOP
12 Deg. Maximum Field
For 6 Subjects, 6 Runs



FUNCTION:

$$G(s)= \frac{Ke^{-sT}}{(1 + s/A)}$$

PARAMETERS:

K= 0.853
A= (2.802)2π=17.606
T= 0.208

8. DISCUSSION

The describing function models for EOG and oculometer tracking presented in Section 7 are intended to describe, in compact form, the relevant overall dynamic properties of these tracking methods. Among the objectives of this project was the determination of the possible effect of maximum target field size on the (describing function) tracking model. Therefore, all the tests were performed at 6, 9 and 12 degrees maximum target field. From the parameter values of Tables 7-1 to 7-3, some relevant observations are summarized in Table 8-1.

For each of the three tracking schemes, Table 8-1 presents the percent changes of the model parameters as the result of maximum target field increase from 6 to 12 degrees. Such values are shown only when the increase or decrease is monotonic. For every case, the range is presented in terms of the percent maximum excursion from the average value, within which each parameter varies. Since the parameters may have different values for azimuth and elevation, the percent increases or decreases, as well as the percent excursions from average values had been obtained separately and then averaged between the two values for azimuth and elevation.

For EOG tracking, both gain K and bandwidth, in terms of model parameter C, decrease with increasing target field size. Typically, such an effect can be caused by an equivalent gain (describing function) in the open-loop that decreases with increasing input-signal strength. Indeed, this is true of the EOG sensing function whose characteristic exhibits saturation.

TABLE 8-1

EFFECT OF INCREASE IN MAXIMUM TARGET FIELD FROM 6 TO 12 DEGREES*

TRACKING METHOD	EOG	OCUL. W/O FB	OCUL. WITH FB
Low-Frequency Gain, K	15% decrease within 10%	6% increase within 3%	---- within 1.4%
Pole Relevant for BW:#	29% decrease within 19%	24% increase within 12%	95% increase within 37%
Transport Lag, T:	---- within 9.2%	22% decrease within 16%	21% increase within 10%

*Average between % change of average value for azimuth and that for elevation. Also shown is the range, in terms of the average between azimuth and elevation, of the % maximum excursion from the average value of the results for different target field sizes.
#The pole relevant for the bandwidth is "C" for EOG and "A" for oculometer tracking, in eqs. (7-1) and (7-2) respectively.

For oculometer tracking, the gain remains fairly constant while the bandwidth, in terms of model parameter A, increases with increasing target field size. The bandwidth increase reflects a slight open-loop gain- enhancement for larger target excursions (see Figures 6-4 to 6-9 for open- loop, as well as closed-loop frequency responses). Interestingly, the relative bandwidth increase (with target field size) for oculometer tracking with visual feedback display (95%) is larger than that for oculometer tracking with visual feedback display (24%). However, from the values in Tables 7-2 and 7-3 it can be seen that the average values of model parameter A are higher for oculometer tracking without visual feedback (FB) display than for that with visual FB display. For all three target field sizes (6, 9 and 12 degrees), the average values are:

For oculometer without visual feedback display:

Azimuth: A = 11.04 Elevation: A = 11.70

For oculometer with visual feedback display:

Azimuth: A = 7.61 Elevation: A = 10.95

Apparently, the somewhat greater bandwidth of oculometer tracking without visual FB is related to the absence of the additional task for the subject to align the control display with that of the target. On the other hand, the tracking accuracy depends on the calibration of the oculometer, whereas in oculometer tracking with visual FB display, the error sensing is done by perceptual means. All oculometer tests were performed after careful calibration (with an estimated accuracy of $\pm 1^{\circ}$).

The tracking accuracy is reflected in the 50% CEP ("ciruclar error probability") which defines the radius about the target (or about a centroid of the error motion) within which the tracking response remained 50% of the run-time. Average values, standard deviations and ranges for the 50% CEP are presented in Figures 6-1 to 6-9, as well as in Tables B-1 to B-9, Figures B-1 to B-9, Appendix B. From these values, it is seen that the 50% CEP is fairly proportional with target field size. In other words, the ratio between 50% CEP (angle) and the maximum target angle is fairly constant. From the data obtained, the average 50% CEP ratio with respect to target angle is:

$$\frac{\text{50\% CEP w.r. to Target (angle)}}{\text{Maximum Target Angle}} = \begin{cases} 0.541 \pm 8\% & \text{for EOG} \\ 0.330 \pm 7\% & \text{for oculometer w/o visual feedback} \\ 0.345 \pm 2\% & \text{for oculometer with visual feedback} \end{cases}$$

Oculometer tracking without visual feedback has the best tracking performance (in terms of the lowest CEP-ratio); however, as mentioned before, this is based on accurate oculometer calibration, which may not be as essential in oculometer tracking with visual feedback. It would appear that for oculometer tracking without visual

feedback, miscalibration (of the oculometer) will introduce a tracking bias but not affect the bandwidth, whereas in oculometer tracking with visual feedback, perceptual error-correction will reduce the tracking bias, but probably at the expense of reduced bandwidth. (see recommendation (b) in Section 9).

9. RECOMMENDATIONS FOR FURTHER STUDY

(a) Describing Function Models for Other Tracking Methods: In the present project. overall properties were established, in the compact form of describing function models, for three tracking methods. The experience gained in this project should serve useful in establishing describing function models for other tracking methods such as, for example, head (helmet) tracking.

(b) Accuracy Requirements for Tracking Methods with Feedback Display: This applies not only to the oculometer tracking with feedback display or EOG tracking studied in this project, but to wider class of tracking methods, such as helmet tracking. Since the actual error-sensing is performed by the human operator, instruments (such as oculometer, helmet sensor or EOG sensor) merely serve as control actuators. Errors in instrument sensitivity affect the open-loop gain but may have little effect on the steady-state tracking error. Moverover, human adaptation may possibly have a compensating effect on the open-loop gain itself. Likewise, any instrument output bias including drift may not directly affect the steady-state tracking error. It would be desirable to investigate how accuracy and dynamic performance, e.g. bandwidth, of tracking (with feedback display) are affected by changes in instrument gain, as well as by bias and drift. Such a project will provide data needed to establish specifications for sensing instruments to be used in practical tracking schemes.

The AMRL tracking laboratory is ideally equipped to produce the data for such a project. Gains and outputs of a reasonably accurate head (helmet) sensor and/or line-of-sight sensor (oculometer) can be modified by constant or random errors.

(c) Effect of Open Loop Gain in Tracking Methods with Feedback Display: Whereas Recommendation (b) above pertains to accuracy effects of instrument gain and bias, this recommended effort seeks to establish optimum open-loop gain for given tracking tasks. All experiments conducted in this project with EOG tracking and oculometer tracking with feedback display, involved unity open-loop gain. This choice appeared "reasonable" but may not necessarily result in optimal tracking performance.

(d) Model Study of Eye-Head Tracking: The tracking schemes considered in this research, including oculometer with and without feedback display, as well as EOG tracking, all involve human eye-head coordination, though each in different ways. For eye tracking itself (with fixed head position), several models have been proposed[11,12,13,14]; however, they may serve, at best, as guides in the search for a model of eye-head tracking, which must include the dynamics of eye-head coordination[15,16]. An important property desired of a model is the identifiability of its element from data of properly chosen tracking experiments.

(e) Reduction of Drift and its Effect in EOG Tracking: Though EOG tracking does not appear promising as a practical method it may be useful in research studies relevant to head-eye coordination. Even with presently available electrodes, drift may not be objectionable, as long as the subject can comfortably exert control. Electronic circuitry can be designed to compensate for drift or to automatically reset the d-c level when the drift exceeds a certain value. Another improvement can be obtained by a circuit that locks the feedback display in case of events such as blinking (such circuitry exists in the Honeywell remote oculometer). One of the problems of any tracking system involving feedback display is the temporary loss of the feedback display. This will cause the subject to go into searching motion. This happened during some of the experiments conducted during the summer, causing reduction of overall tracking performance. It is possible, however, to prevent this from happening by limiting the display such that it never leaves the boundaaries of the visual field.

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APPENDIX A

INDIVIDUAL TRACKING RUN RESULTS

Presented in this appendix are the frequency response plots for the individual tracking runs on 11 (of the 15) subjects.* Also shown for each test run presented are the values of the 50% circular error probability (CEP - the radius within which the tracking error remains within 50% of the run time; both with reference to the target and to the centroid of the error motion.* Each plate represents a tracking run; for each azimuth and elevation, it shows the gain and phase versus frequency plots for

$$\text{"Closed-Loop", meaning: } \frac{\text{Control (output)}}{\text{Target (output)}}$$

$$\text{"Open - Loop", meaning: } \frac{\text{Control (output)}}{\text{Error (Target minus Control)}}$$

Table A-1 summarizes the relevant data on the target forcing function used for the tracking runs, whose results have been processed.

In total, 100 EOG tracking runs on 15 subjects and 48 oculometer runs (24 each with and without visual feedback display) on 6 (of the 15) subjects have been processed. For lack of space, this appendix shows individual frequency response plots for only 72 EOG tracking runs on 11 subjects and 24 oculometer tracking runs on 3 (of those 11) subjects. The remaining individual frequency response plots are quite similar but their data are, of course, incorporated in the computation of the average responses presented in the body of this report.

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*The frequency response data and the 50% CEP values were computed on the PDP-11/34 minicomputer at the AMRL Tracking Laboratory, using programs "MODFRT" and "TR4" respectively.

TABLE A-1

SPECIFICATION OF FORCING FUNCTIONS USED IN THE TRACKING RUNS

FREQUENCIES(Hertz)		
Azimuth	Elevation	Sum-of-sines: 10 frequencies between (approx.) 0.1 Hertz and 3.0 Hertz as shown.
0.09888		
	0.12085	For a set of runs on a subject three forcing
0.14282		functions were used which were identical in every-
	0.17578	thing except for different (randomly selected)
0.20874		phases of their sine-wave components; they are de-
	0.25269	signated by forcing function (FF) numbers 1, 2 and
0.30762		3 and their sequence in any series of tracking
	0.37354	runs was permuted as shown in Tables A-2 and A-3
0.45044		for EOG and oculometer tracking respectively.
	0.54932	
0.65918		Break Frequencies (6 dB Power):
	0.80200	
0.96680		Subject 0 (5 EOG runs): Different break frequen-
	1.16455	cies: 0.7, 0.8, 0.9 and 1.0 Hertz
1.40625		(4 FF's; 0.8 Hz was used twice).
	1.70288	
2.05444		Practice Runs (On All Subjects 1-14): 0.7 Hertz;
	2.48291	One FF (FF number P).
2.99927		
	3.62549	Subjects 1 and 2: 1.0 Hertz;
		Three FF's (FF numbers 1,2,3).
		Subjects 3 Through 14: 0.8 Hertz;
		Three FF's (FF numbers 1,2,3).

The tracking runs on subject 0 represents test runs, using EOG tracking, all for 6 degree maximum target field but for different (6 dB power) break frequencies, namely 0.7, 0.8, 0.9 and 1.0 Hertz.

The tracking runs on Subjects 1 and 2 used forcing functions with a break frequency of 1.0 Hertz. However, it was found that the evaluated results may not be reliable. This may be seen by the markings of the data points in terms of the "reliability levels" defined in Table 5-1. It was therefore decided to lower the break frequency for all subsequent tracking runs to 0.8 Hertz for Subjects 3 through 14.

All data evaluations presented in Section 6 have been based on the tracking runs for Subjects 3 to 14, with a break frequency of 0.8 Hertz; namely 81 EOG runs on 12 subjects and 48 oculometer runs on 6 (of those 12) subjects.

For each subject, the first tracking run was performed with forcing function P (for practice), where the break frequency was 0.7 Hertz. This test run was performed with a maximum target field size of 6 degrees. The subsequent tracking runs were performed with maximum target field sizes of 6, 9 and 12 degrees, the sequence being permuted. Also permuted were the forcing functions which were the same except for the (randomly selected) phases (of the 10 different sine functions). The record of the tracking runs for subjects 1 to 14 is shown in Tables A-1 and A-2 for EOG and oculometer tracking respectively.

The average responses presented in the body of this report are based on the tracking runs on Subjects 3 through 14, for which the target forcing functions all had the same break frequency of 0.8 Hertz.

TABLE A-2

RECORD OF EOG RUNS

No.	Subject	(Age)	Sex	Date (1979)	Maximum Field / Forcing Function Number* For Run 0	1	2	3	4	5	6
1	NM	(28)	F	8/6	6°/P	12°/2	9°/3	6°/1	9°/3	12°/1	6°/2
2	DMF	(20)	F	8/7	6°/P	6°/2	6°/3	12°/1	6°/2	12°/3	9°/1
3	WSS	(67)	M	8/8	6°/P	9°/1	6°/3	12°/2	12°/2	6°/1	9°/3
4	TAC	(24)	M	8/9	6°/P	6°/1	9°/2	12°/3	9°/1	6°/2	(12°/3)**
5	MMP	(22)	F	8/9	6°/P	(12°/2)**	6°/1	9°/3	12°/1	9°/3	6°/2
6	AMK	(36)	M	8/10	6°/P	9°/3	12°/1	6°/2	6°/3	9°/2	(12°/1)**
7	WLG	(32)	M	8/12	6°/P	6°/3	12°/2	9°/1	12°/1	9°/2	6°/3
8	AMW	(19)	F	8/13	6°/P	6°/3	12°/2	9°/1	6°/3	12°/2	9°/1
9	LL	(35)	F	8/13	6°/P	6°/1	9°/3	12°/2	6°/2	9°/1	12°/3
10	CJA	(30)	M	8/14	6°/P	9°/2	6°/1	12°/3	9°/3	6°/1	12°/2
11	KRA	(18)	F	8/15	6°/P	12°/1	6°/2	9°/3	9°/1	12°/3	6°/2
12	DWR	(35)	M	8/15	6°/P	12°/3	9°/1	6°/2	12°/2	6°/3	9°/1
13	MRB	(25)	F	8/17	6°/P	6°/2	9°/3	12°/1	9°/3	12°/1	6°/2
14	AK	(21)	F	8/17	6°/P	9°/1	6°/3	12°/2	12°/2	6°/1	9°/3

*For example, $9^{o}/3$ means " 9 degrees max. field and forcing function (FF) number 3". See Table A-1 for specification of FF's and list of break frequencies of FF's.

**Records lost or damaged during processing (three runs as indicated).

TABLE A-3

RECORD OF OCULOMETER RUNS

No.	Subject	(Age)	Sex	Date (1979)	Maximum Field / Forcing Function Number* For Runs Without Visual Feedback				For Runs With Visual Feedback			
					0	1	2	3	0	1	2	3
8	AMW	(19)	F	8/13	6°/P	9°/3	12°/2	6°/1	6°/P	12°/1	9°/2	6°/3
9	LL	(35)	F	8/13	6°/P	6°/3	12°/2	9°/1	6°/P	6°/3	12°/2	9°/1
10	CJA	(30)	M	8/14	6°/P	6°/1	9°/3	12°/2	6°/P	6°/2	9°/1	12°/3
11	KRH	(18)	F	8/15	6°/P	9°/2	6°/1	12°/3	6°/P	9°/3	6°/1	12°/2
12	DWR	(35)	M	8/15	6°/P	12°/1	6°/2	9°/3	6°/P	9°/1	12°/3	6°/2
13	MRB	(25)	F	8/17	6°/P	12°/3	9°/1	6°/2	6°/P	12°/2	6°/3	9°/1

*See footnote under Table A-2.

Figure A-1

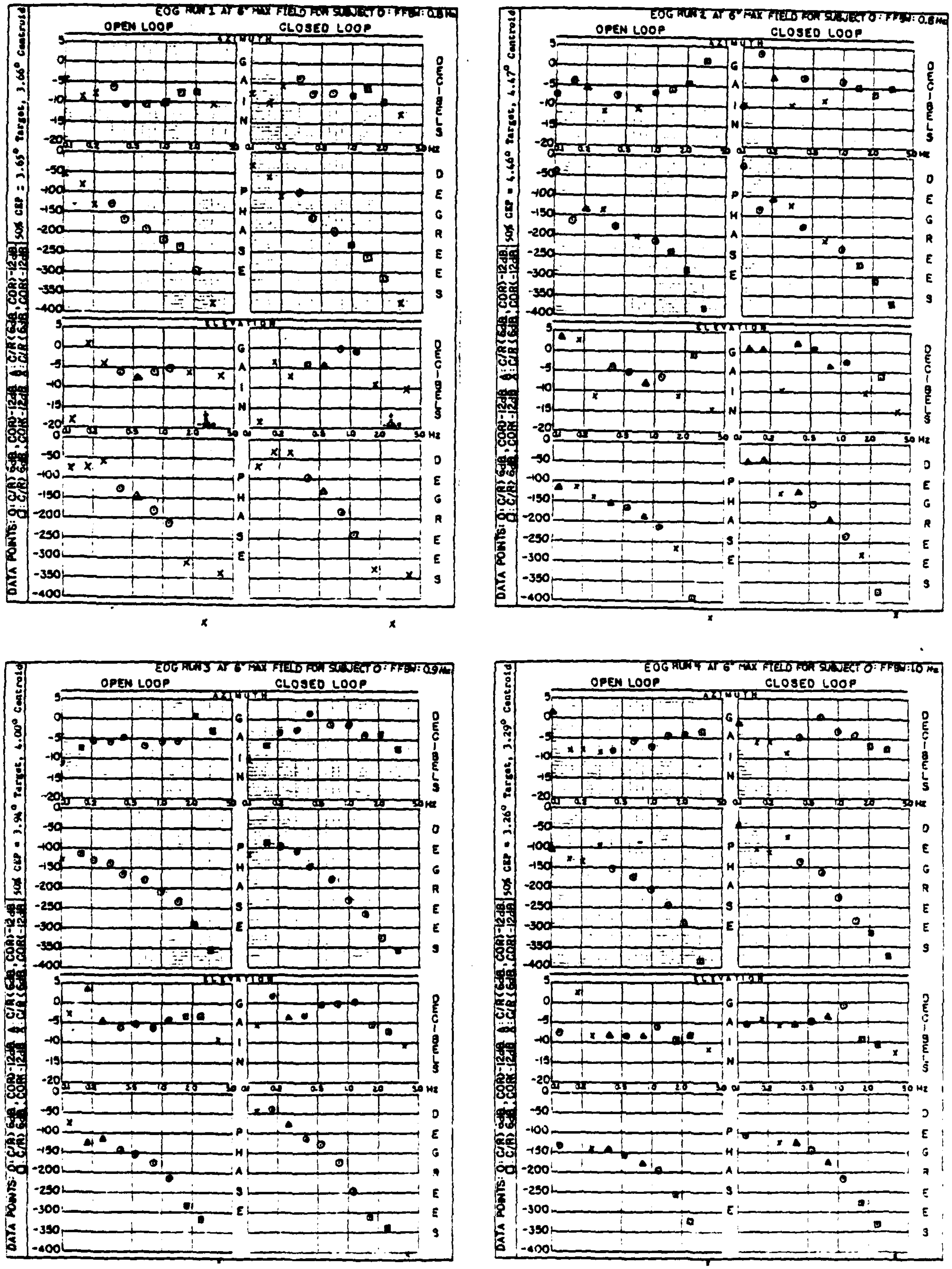

EOG RUN 1 AT 6° MAX FIELD FOR SUBJECT O: FFBW: 0.8 Hz
50% CEP = 3.65° Target, 3.66° Centroid
EOG RUN 2 AT 6° MAX FIELD FOR SUBJECT O: FFBW: 0.8 Hz
50% CEP = 4.46° Target, 4.47° Centroid
EOG RUN 3 AT 6° MAX FIELD FOR SUBJECT O: FFBW: 0.9 Hz
50% CEP = 3.94° Target, 4.00° Centroid
EOG RUN 4 AT 6° MAX FIELD FOR SUBJECT O: FFBW: 1.0 Hz
50% CEP = 3.26° Target, 3.29° Centroid
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz

Figure A-1 (cont.)

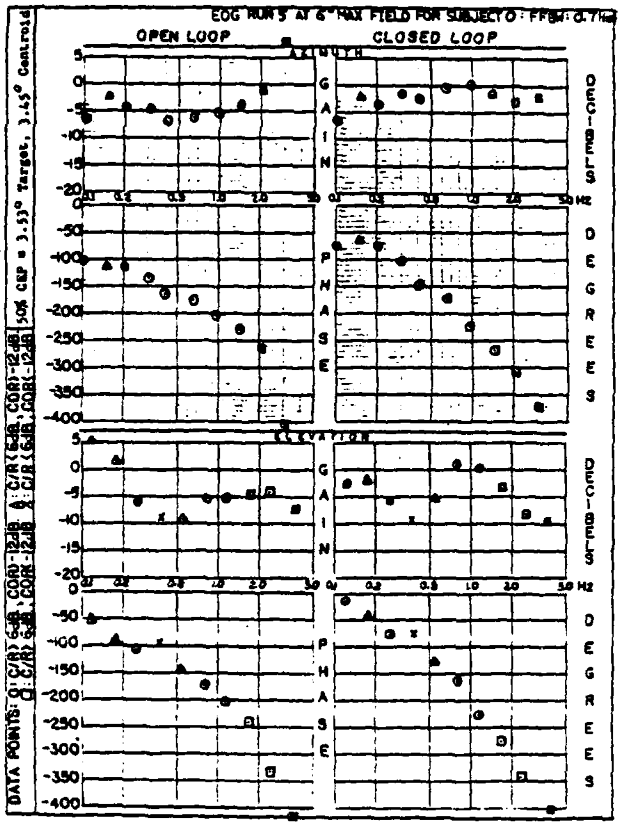
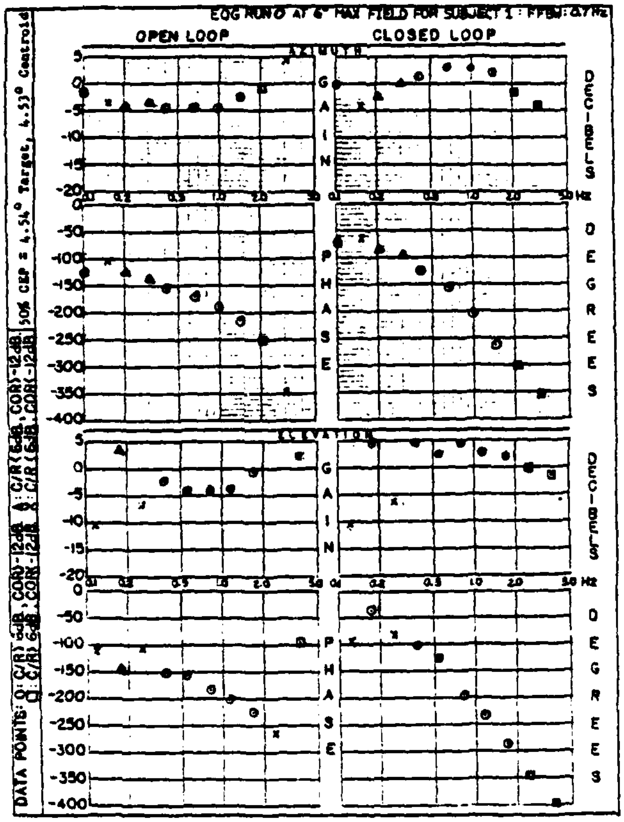
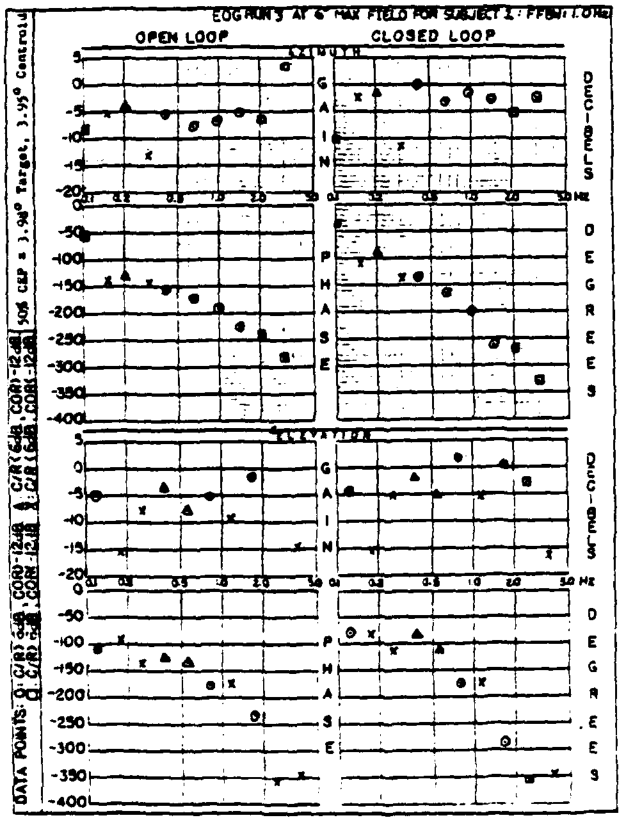


Figure A-2


OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
DATA POINTS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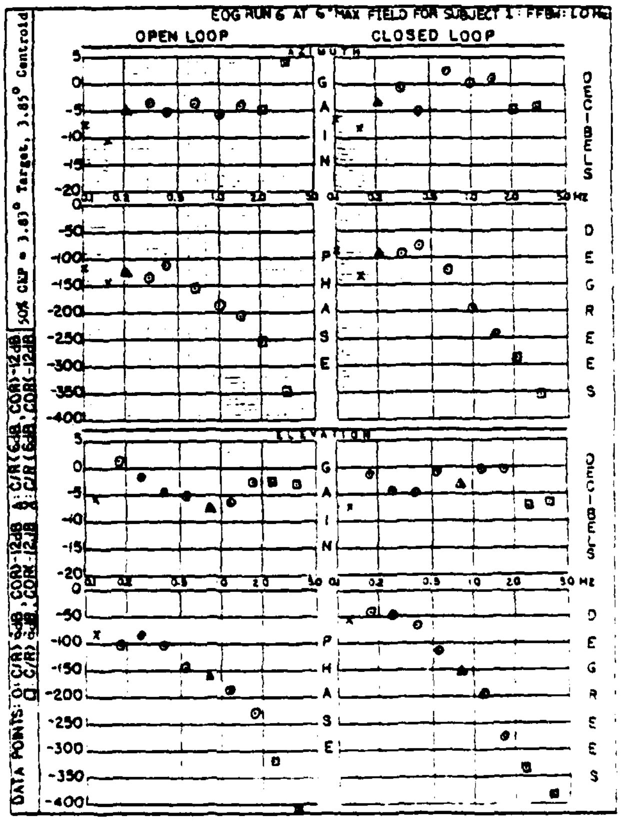
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
DATA POINTS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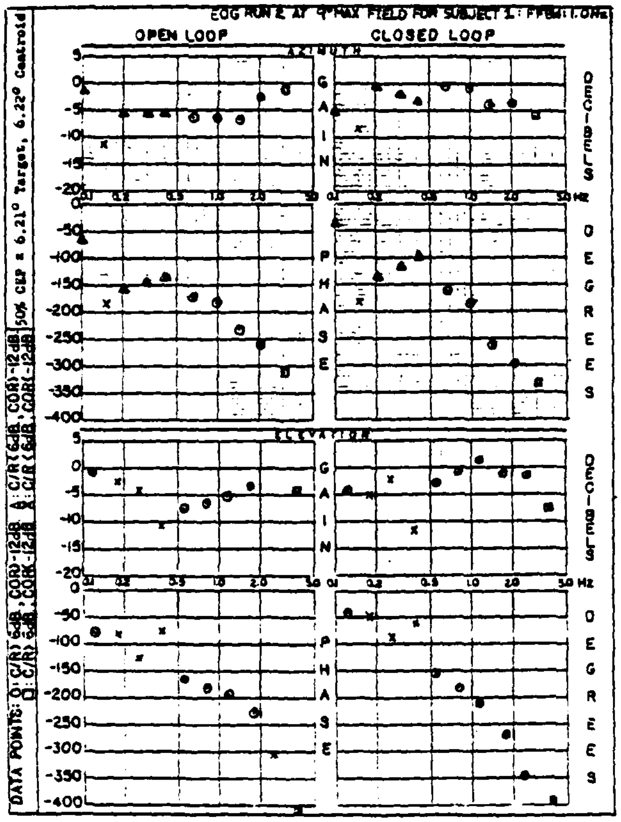
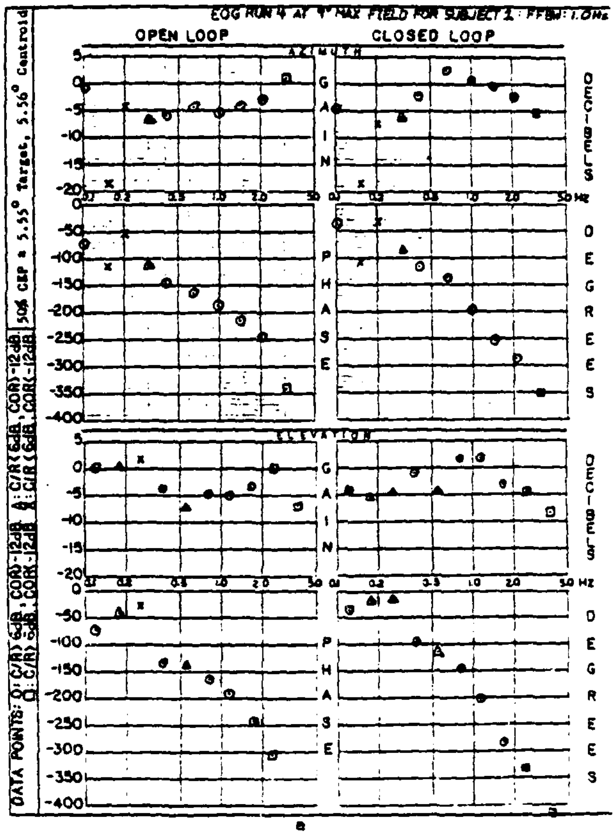
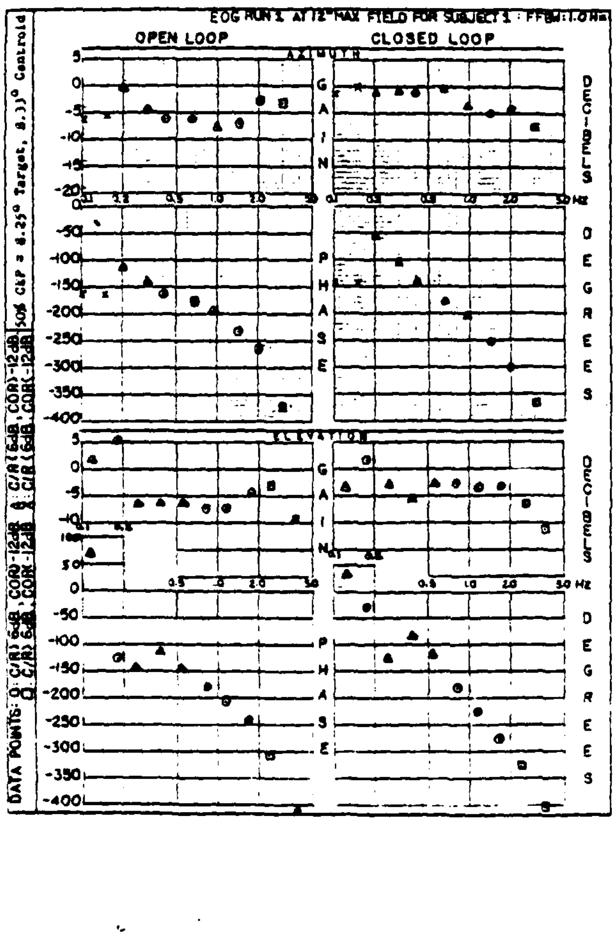
GAIN
PHASE
DECIBELS
DEGREES
DATA POINTS

Figure A-2 (cont.)







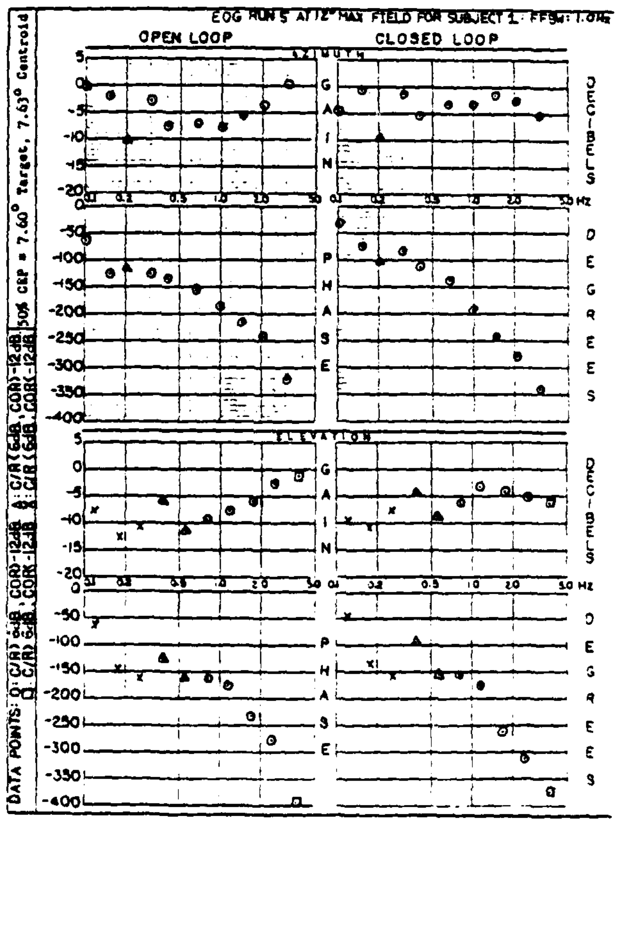


Figure A-3

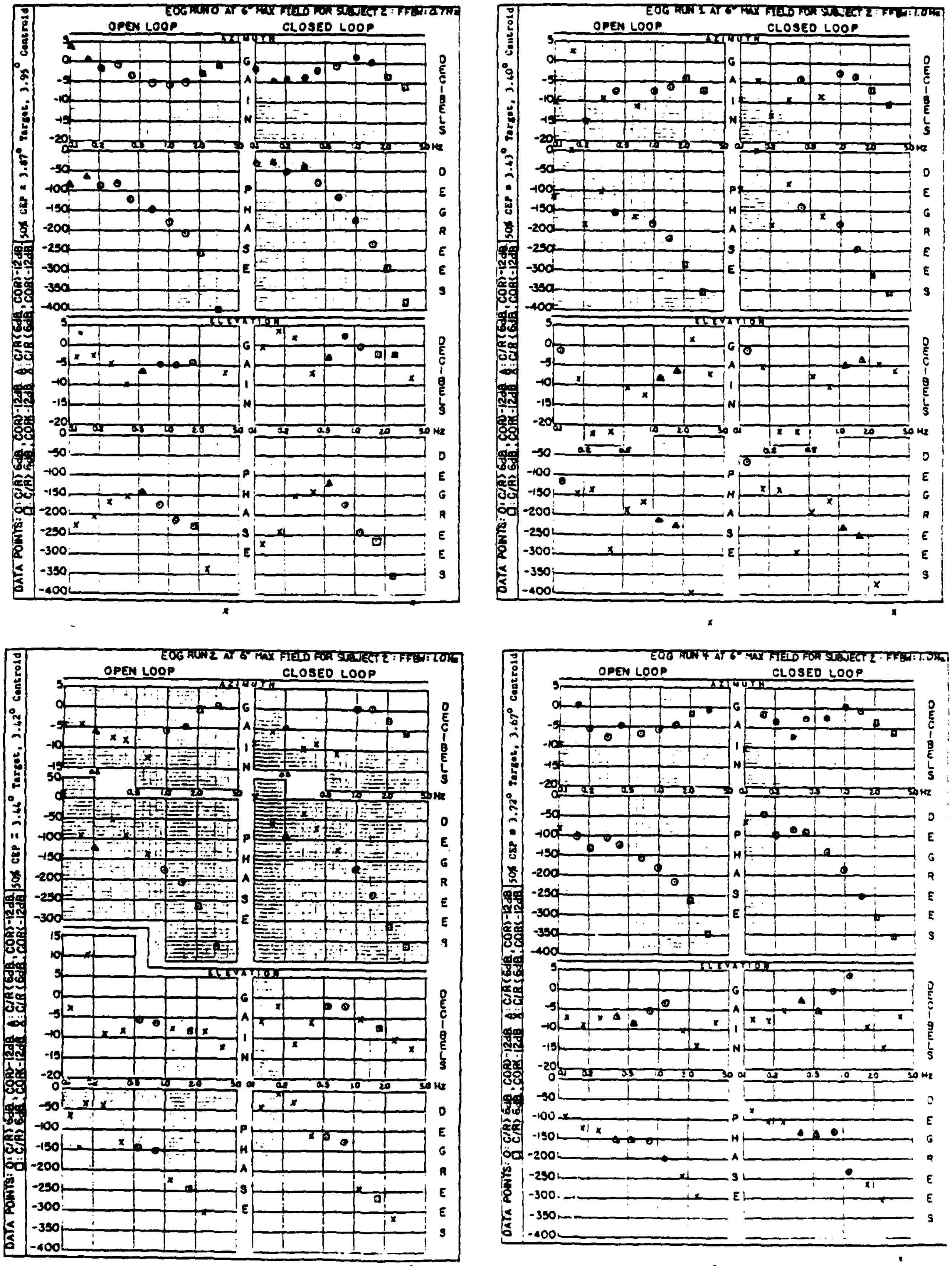
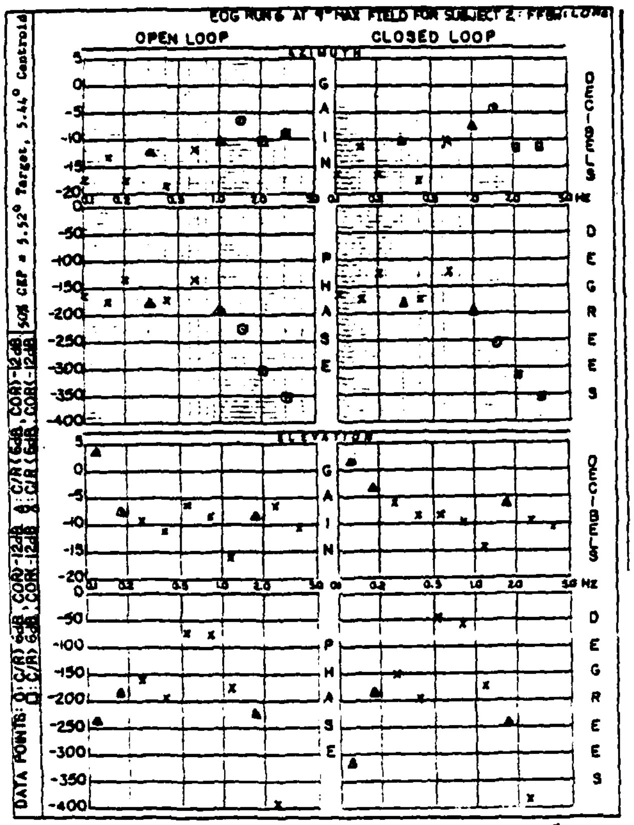
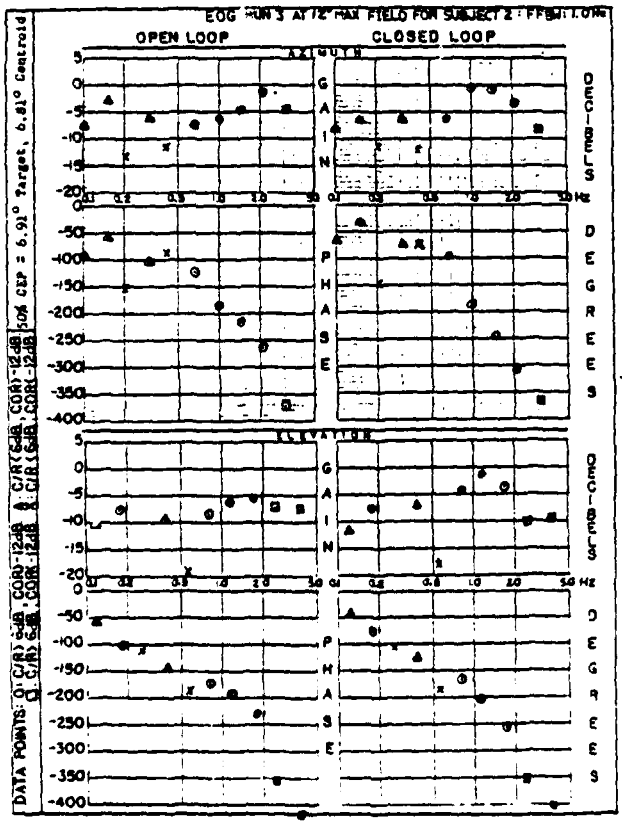

EOG RUN 0 AT 6" MAX FIELD FOR SUBJECT 2 : FFBW: 0.7Hz
EOG RUN 1 AT 6" MAX FIELD FOR SUBJECT 2 : FFBW: 1.0Hz
EOG RUN 2 AT 6" MAX FIELD FOR SUBJECT 2 : FFBW: 1.0Hz
EOG RUN 4 AT 6" MAX FIELD FOR SUBJECT 2 : FFBW: 1.0Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
DATA POINTS: O: C/R(6dB, COR)-12dB △: C/R(6dB, COR)-12dB □: C/R(6dB, COR)-12dB X: C/R(6dB, COR)-12dB
50% CEP = 3.87° Target, 3.95° Centroid
50% CEP = 3.43° Target, 3.40° Centroid
50% CEP = 3.44° Target, 3.42° Centroid
50% CEP = 3.72° Target, 3.67° Centroid

Figure A-3 (cont.)





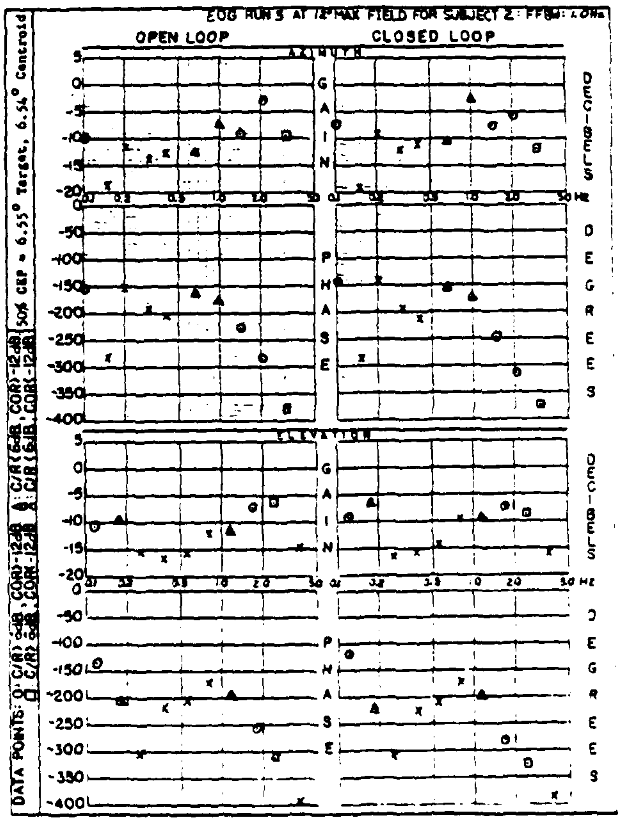
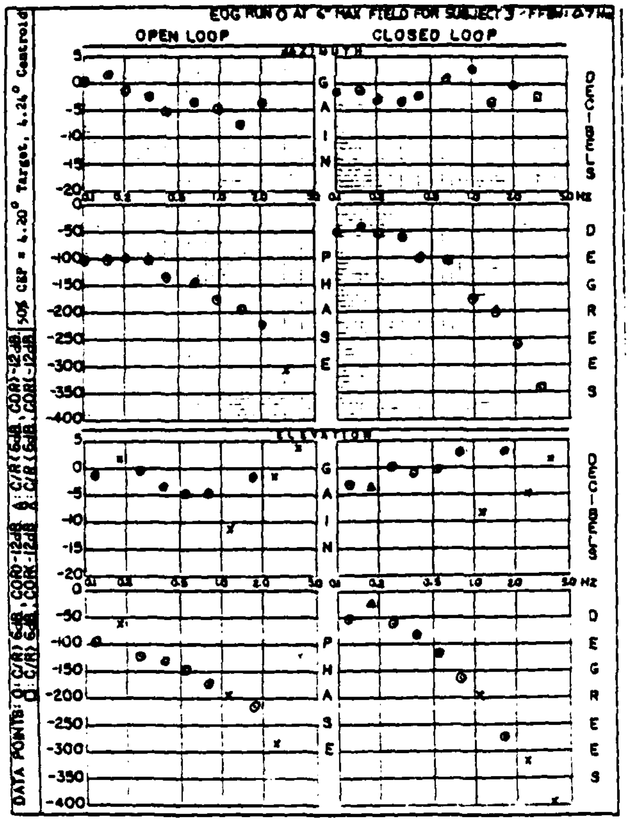
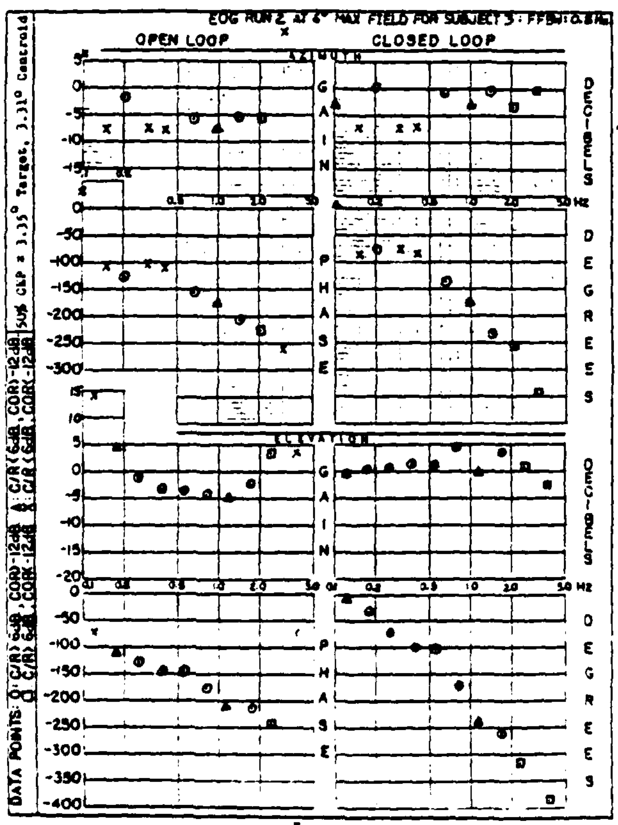


Figure A-4


EOG RUN 0 AT 6" MAX FIELD FOR SUBJECT 3
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
DATA POINTS
50% CEP = 4.20° Target, 4.24° Centroid


EOG RUN 2 AT 6" MAX FIELD FOR SUBJECT 3
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
DATA POINTS
50% CEP = 3.35° Target, 3.31° Centroid

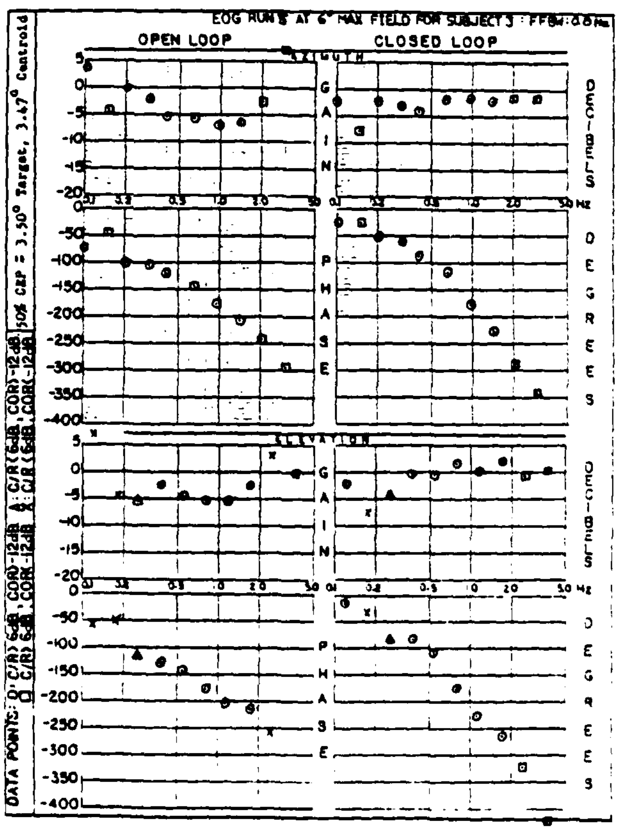

EOG RUN 3 AT 6" MAX FIELD FOR SUBJECT 3
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
DATA POINTS
50% CEP = 3.50° Target, 3.47° Centroid

Figure A-4 (cont.)

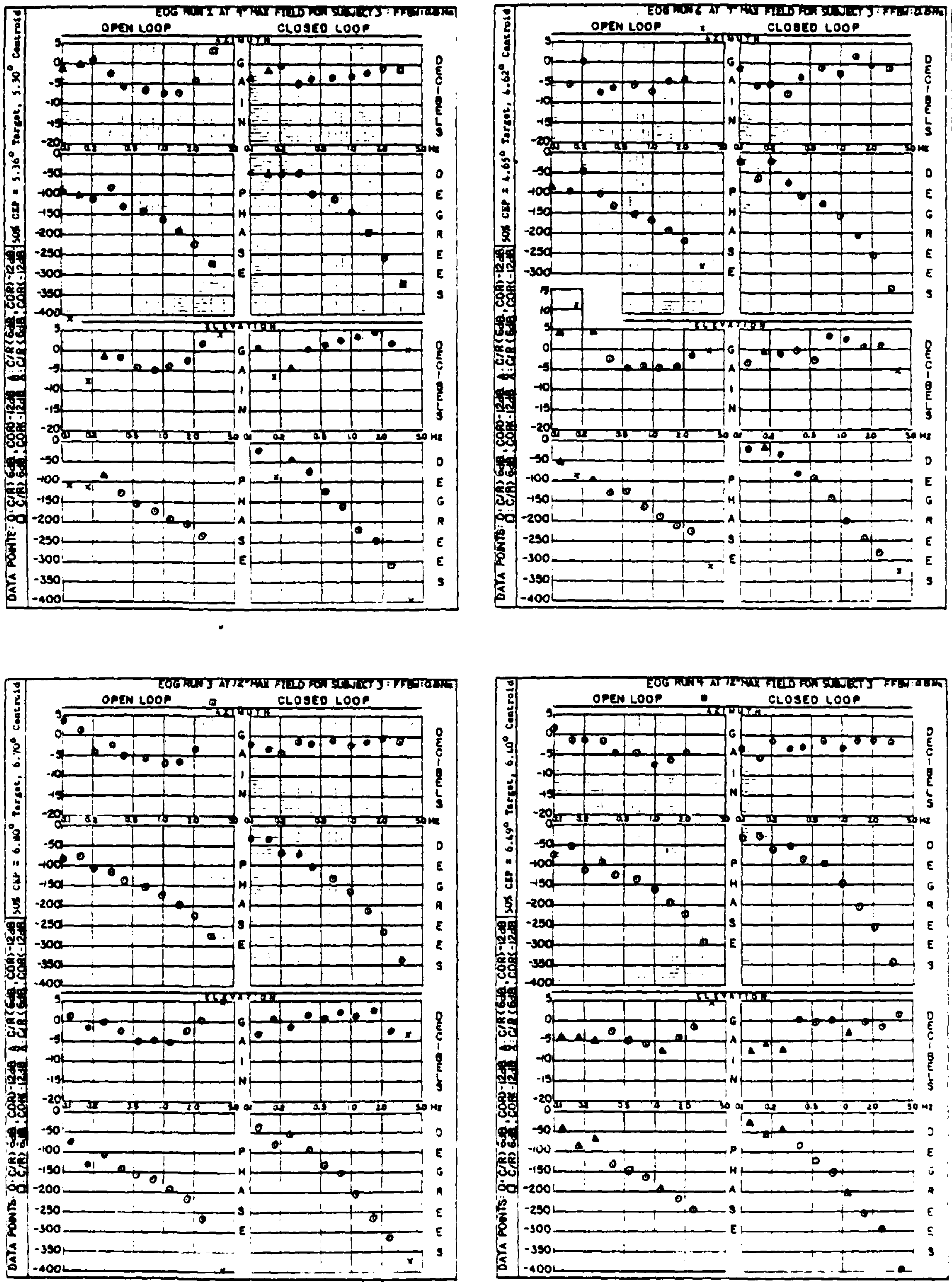
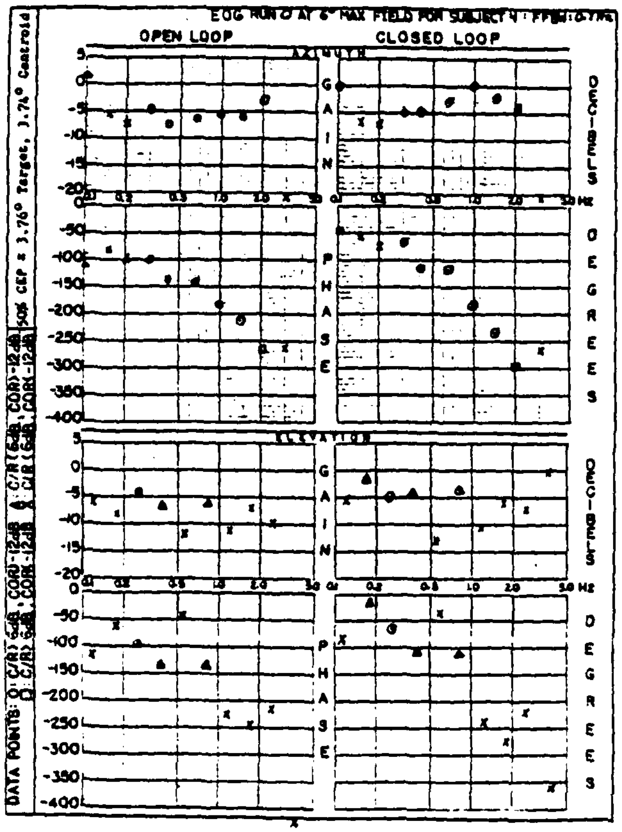
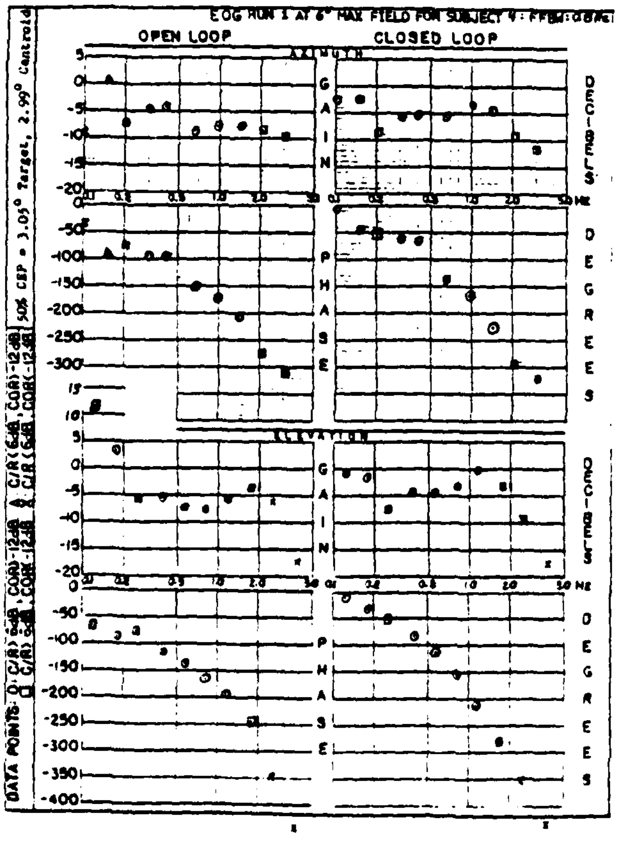


Figure A-5


OPEN LOOP
CLOSED LOOP
GAIN
PHASE
DECIBELS
DEGREES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PHASE
DECIBELS
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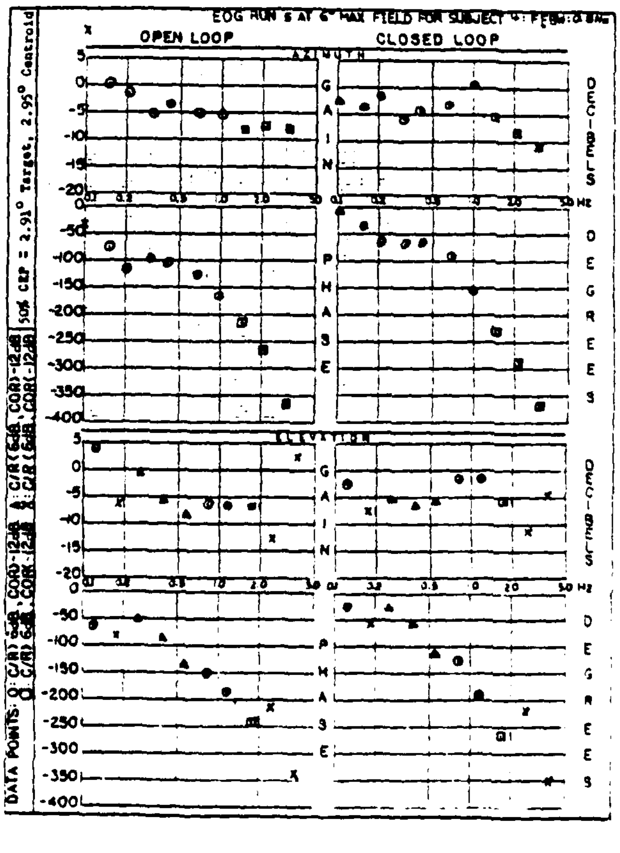
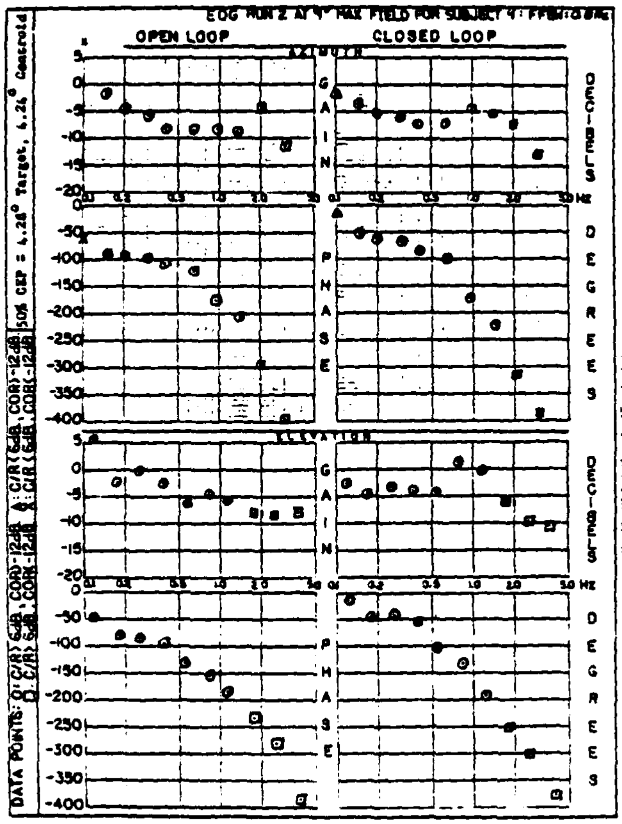
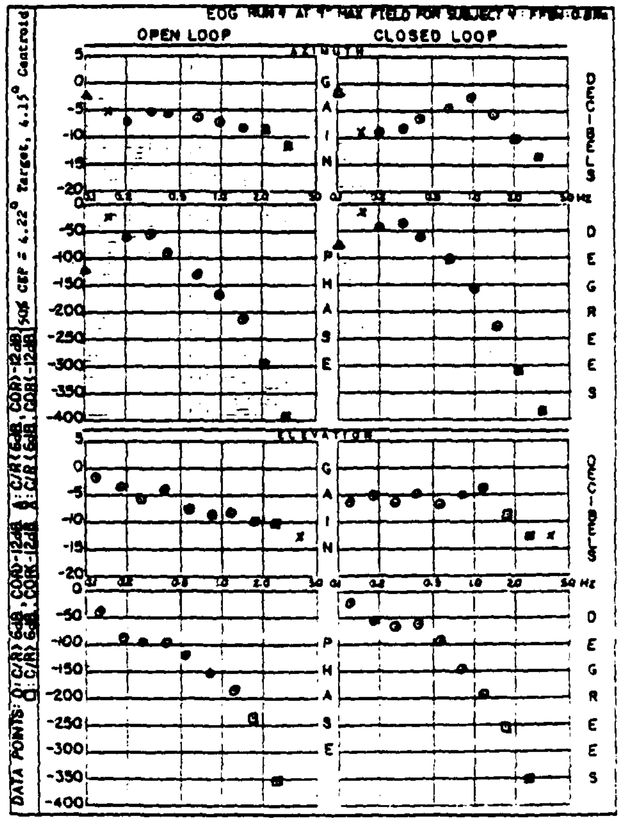

OPEN LOOP
CLOSED LOOP
GAIN
PHASE
DECIBELS
DEGREES

Figure A-5 (cont.)





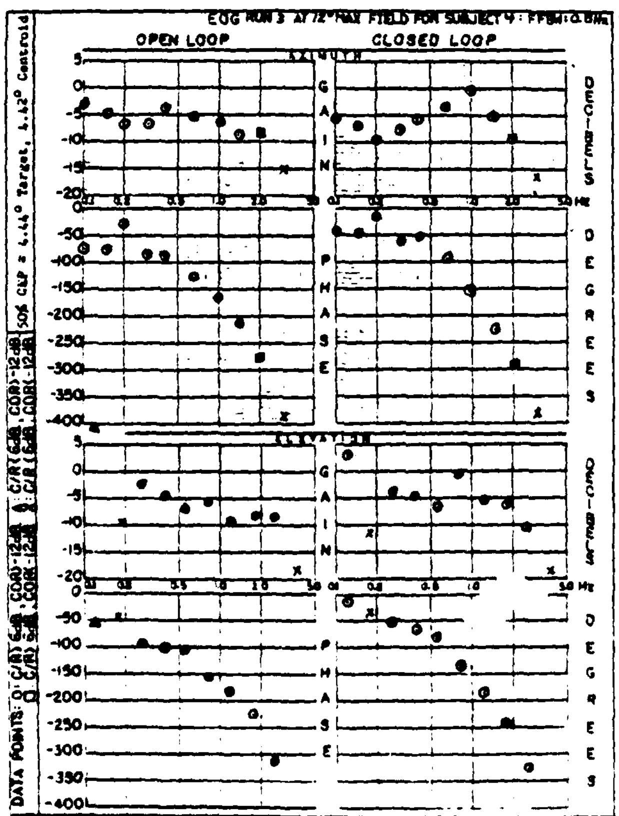
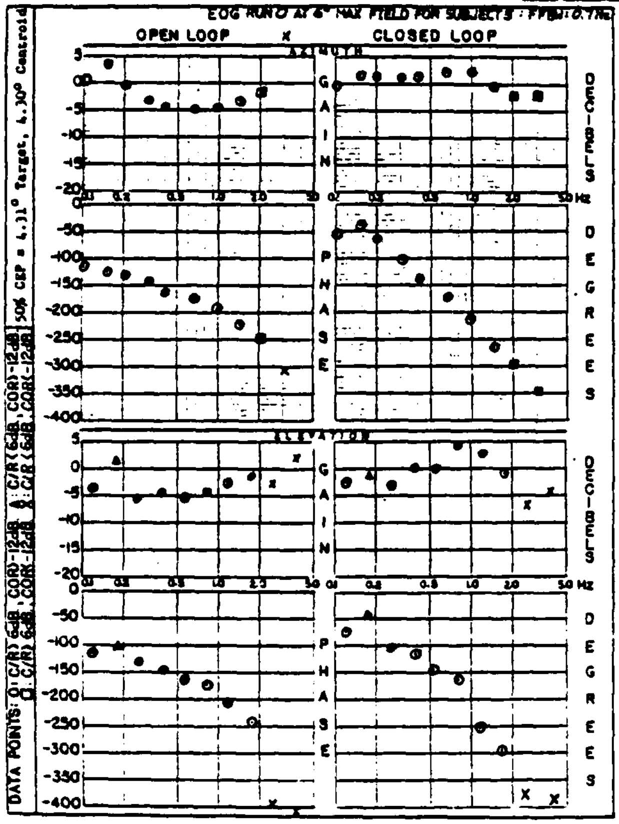
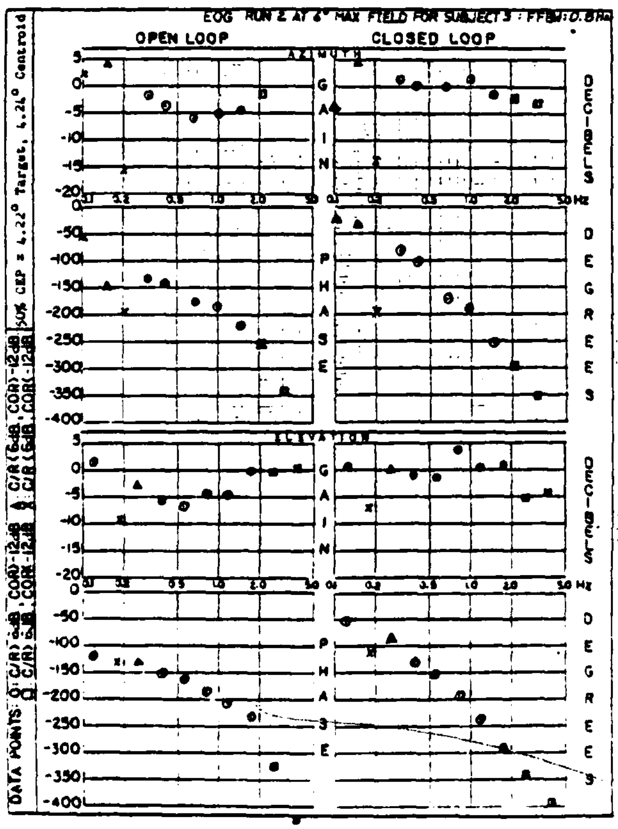


Figure A-6


OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES


OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES

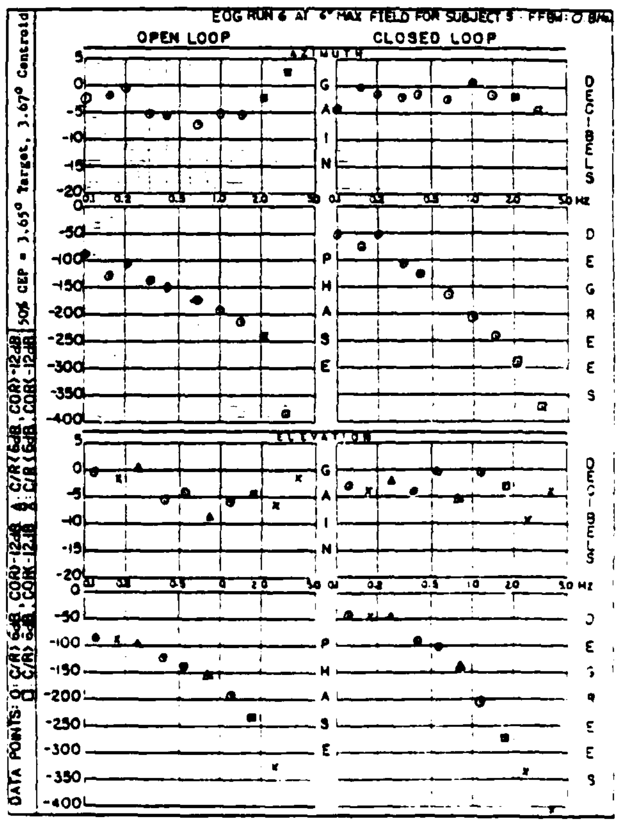
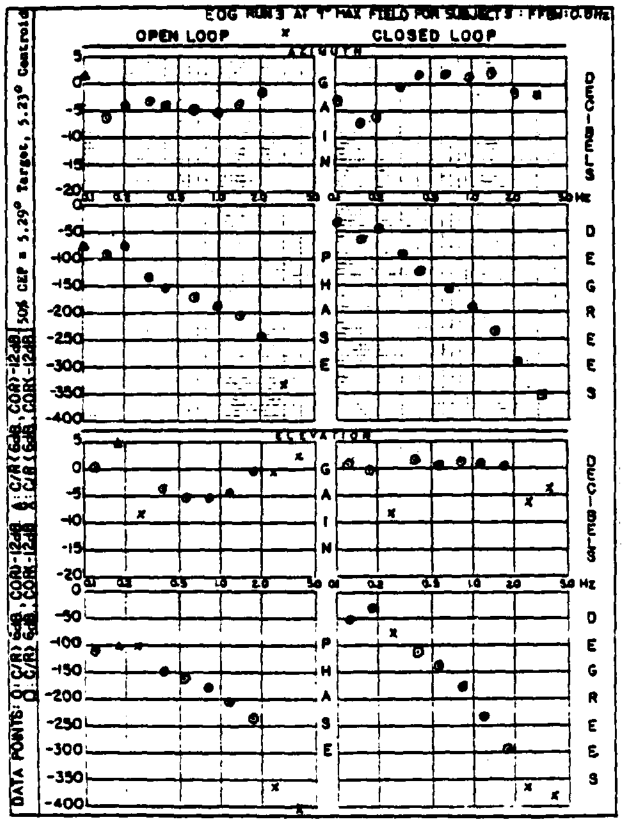
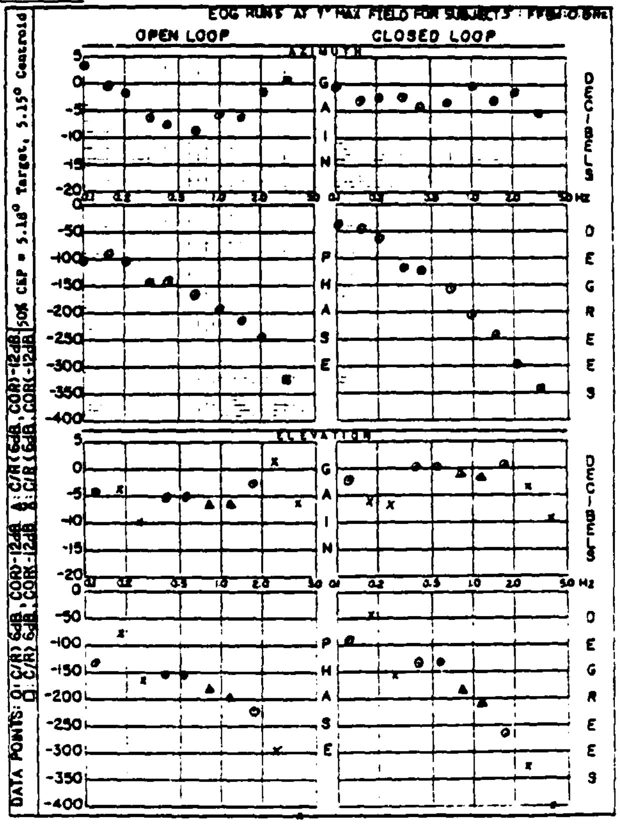

OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES

Figure A-6 (cont.)





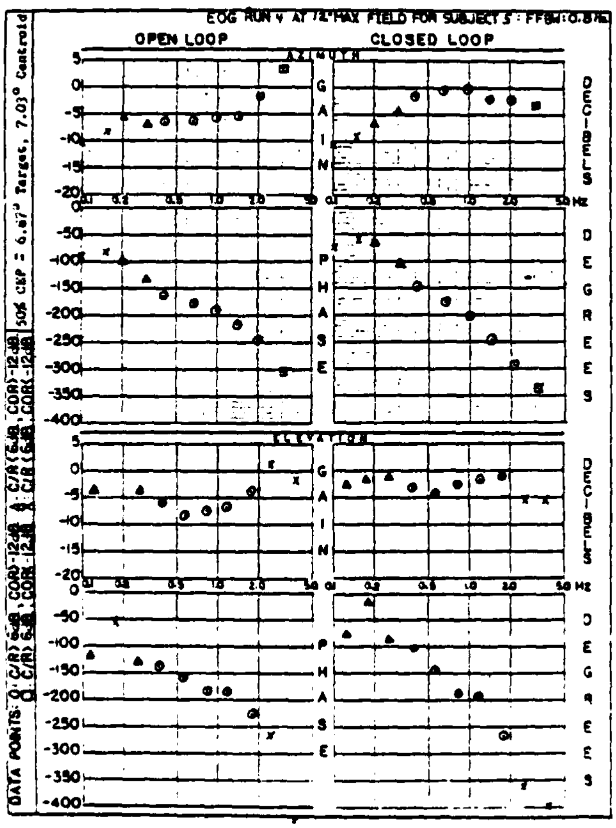
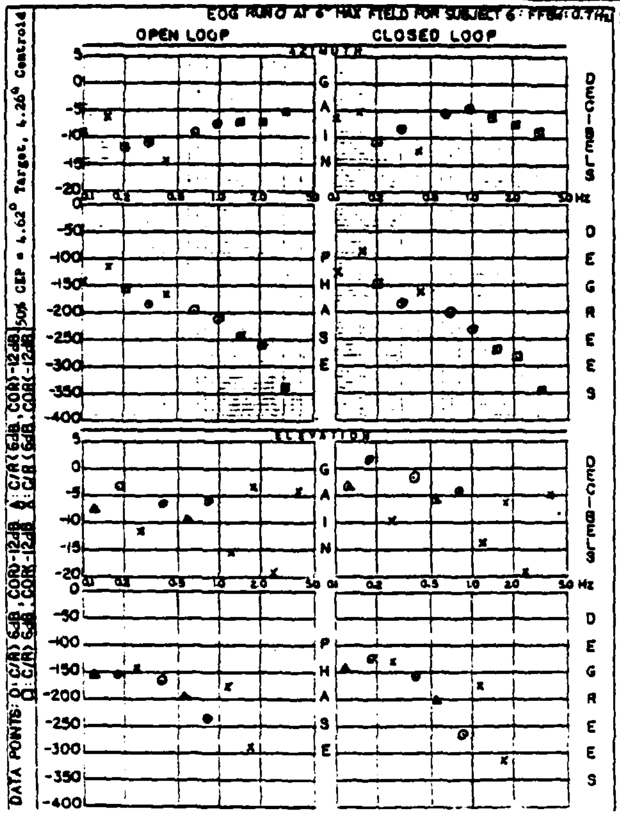
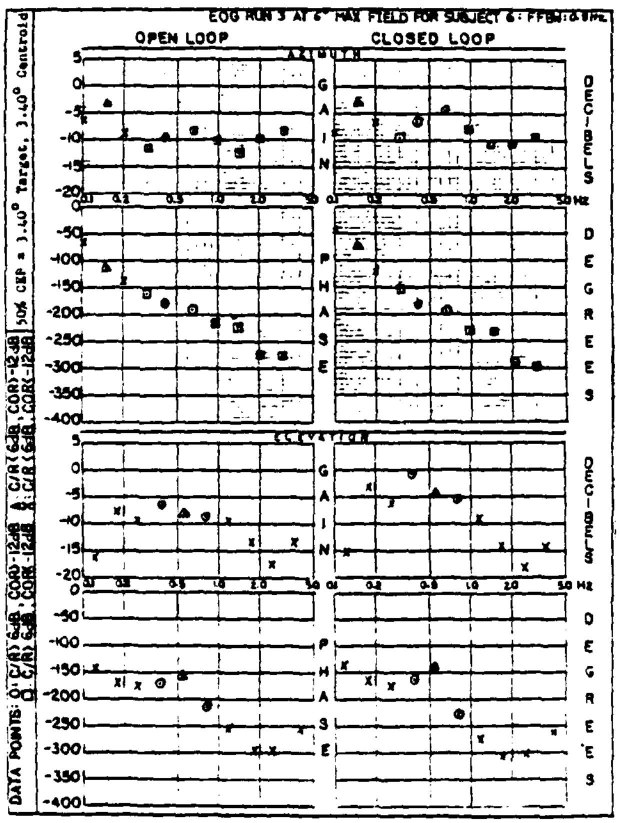


Figure A-7


OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES


EOG RUN 3 AT 6° MAX FIELD FOR SUBJECT 6
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES

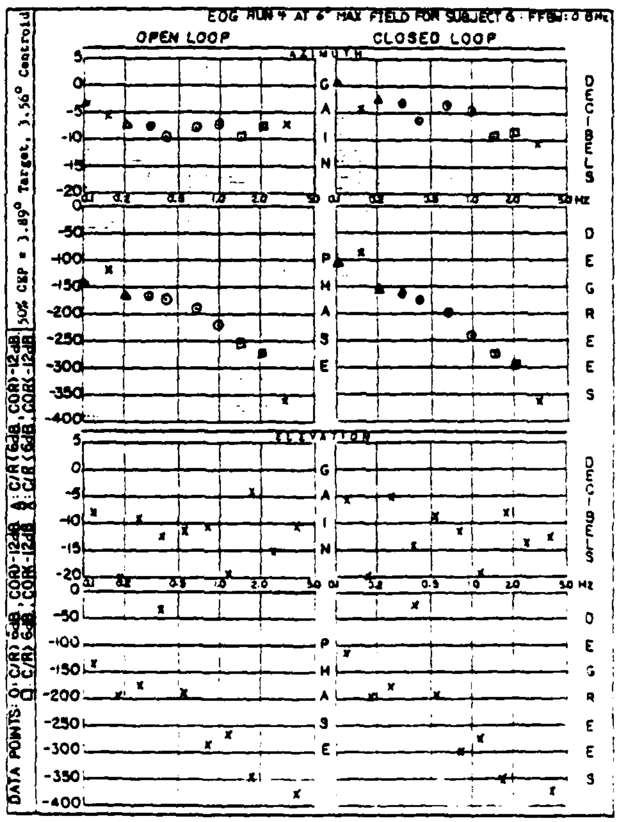
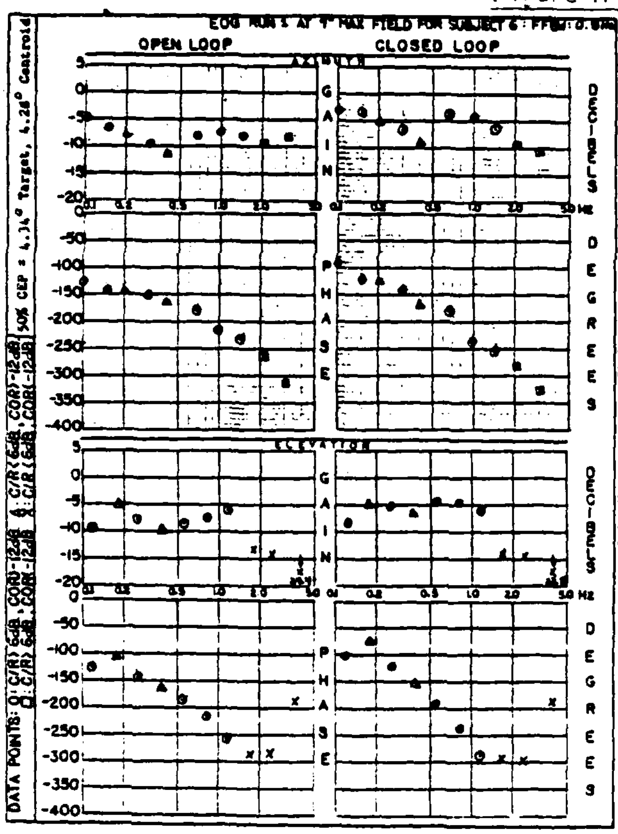
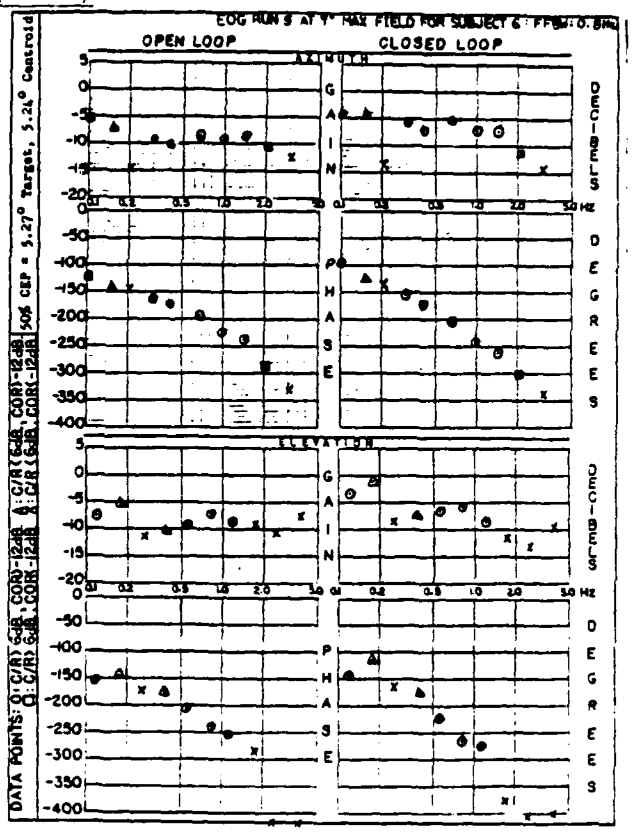

EOG RUN 4 AT 6° MAX FIELD FOR SUBJECT 6
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES

Figure A-7 (cont.)





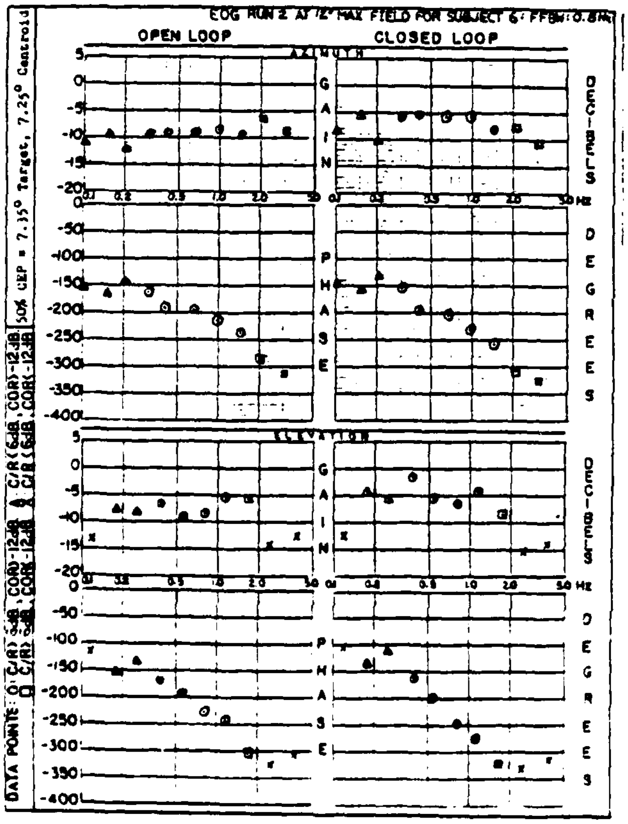
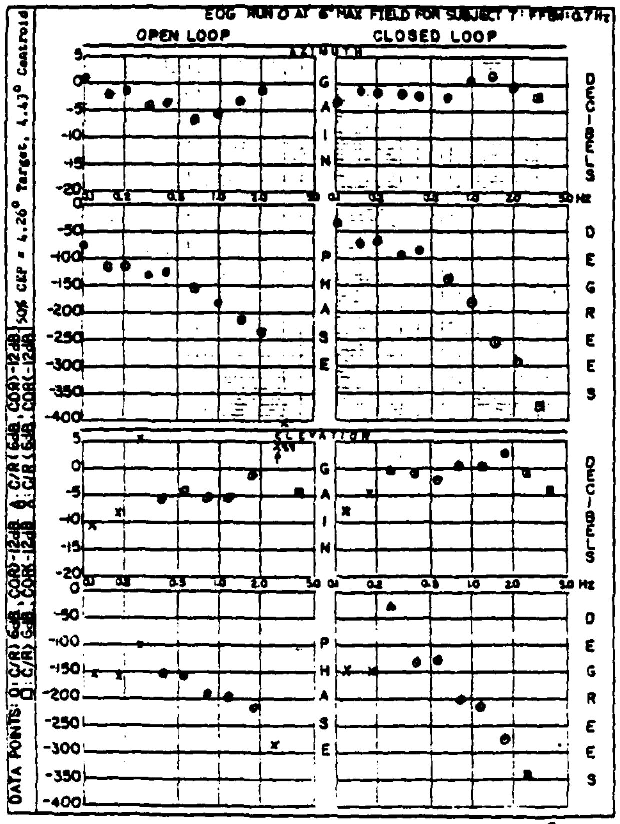
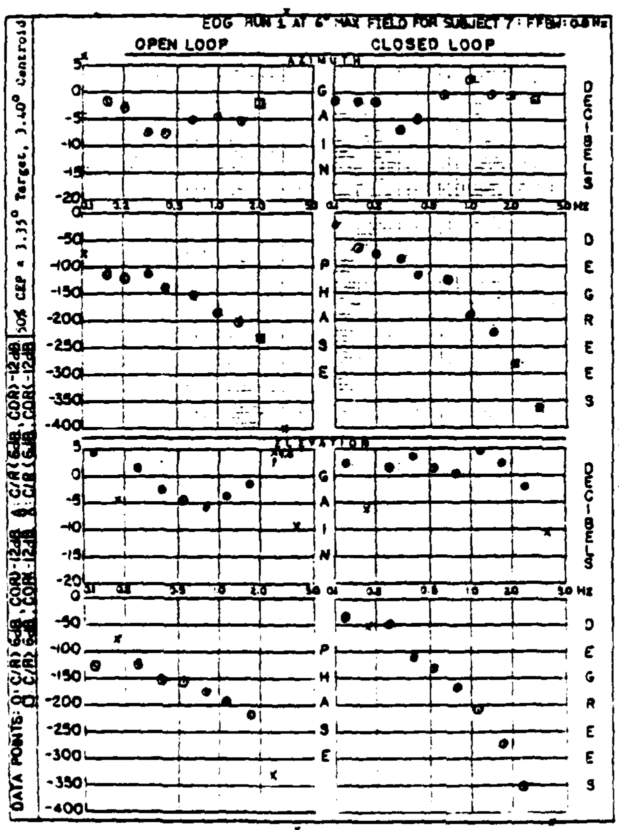


Figure A-8


EOG RUN 0 AT 6° MAX FIELD FOR SUBJECT 7: FFBW: 0.7 Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
50% CEP = 4.26° Target, 4.43° Centroid
DATA POINTS


EOG RUN 1 AT 6° MAX FIELD FOR SUBJECT 7: FFBW: 0.8 Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
50% CEP = 3.35° Target, 3.40° Centroid
DATA POINTS

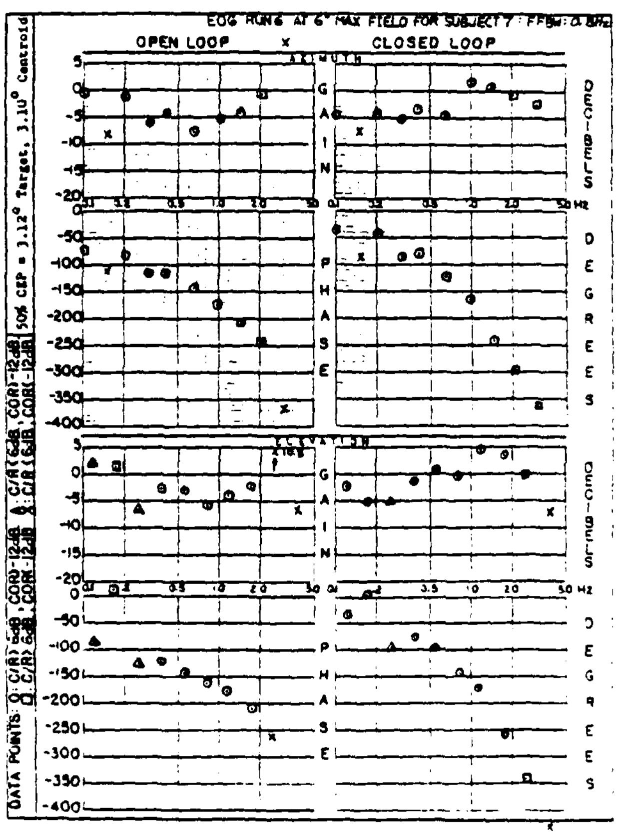
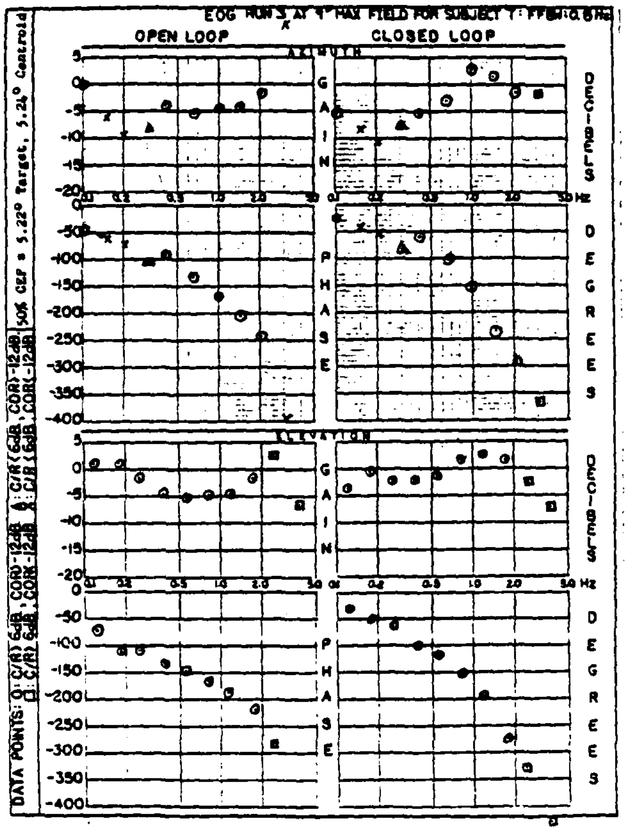
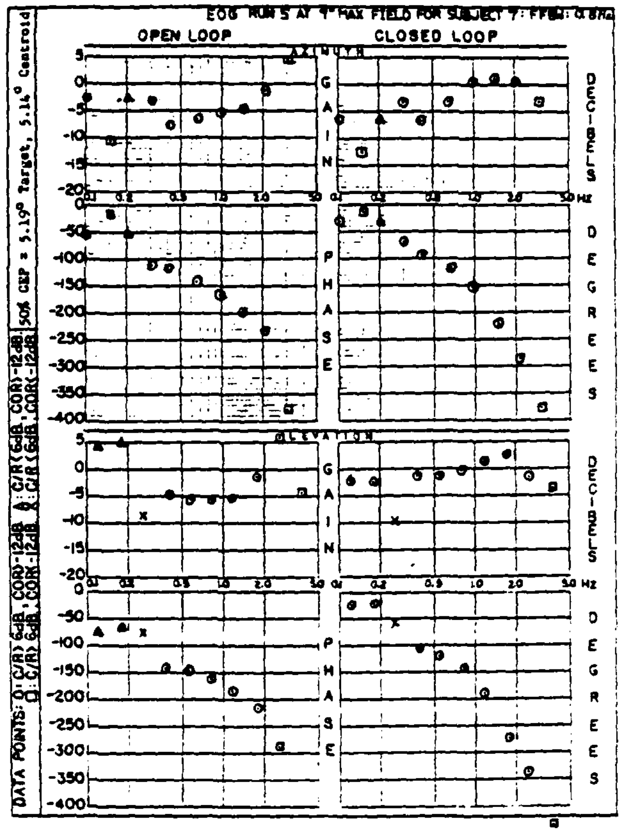
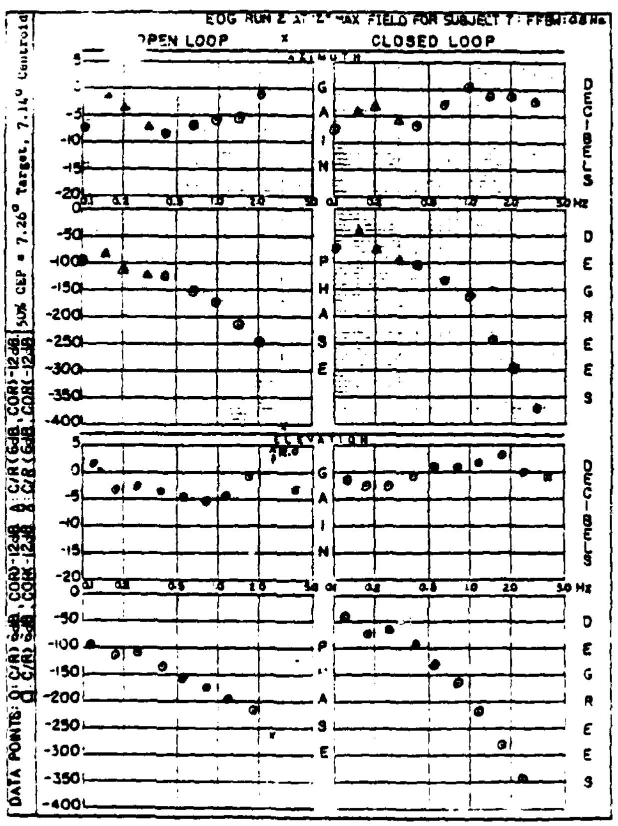

EOG RUN 6 AT 6° MAX FIELD FOR SUBJECT 7: FFBW: 0.8 Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
50% CEP = 3.12° Target, 3.10° Centroid
DATA POINTS

Figure A-8 (cont.)







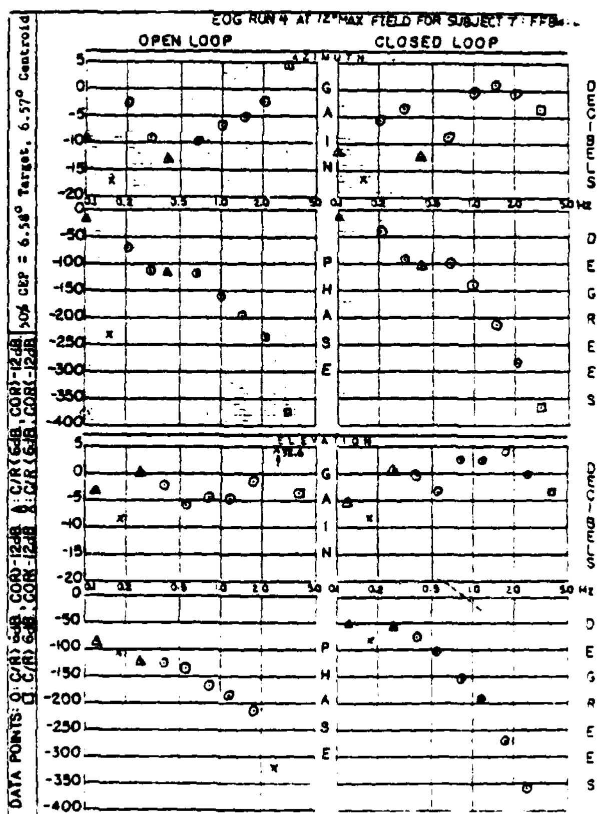
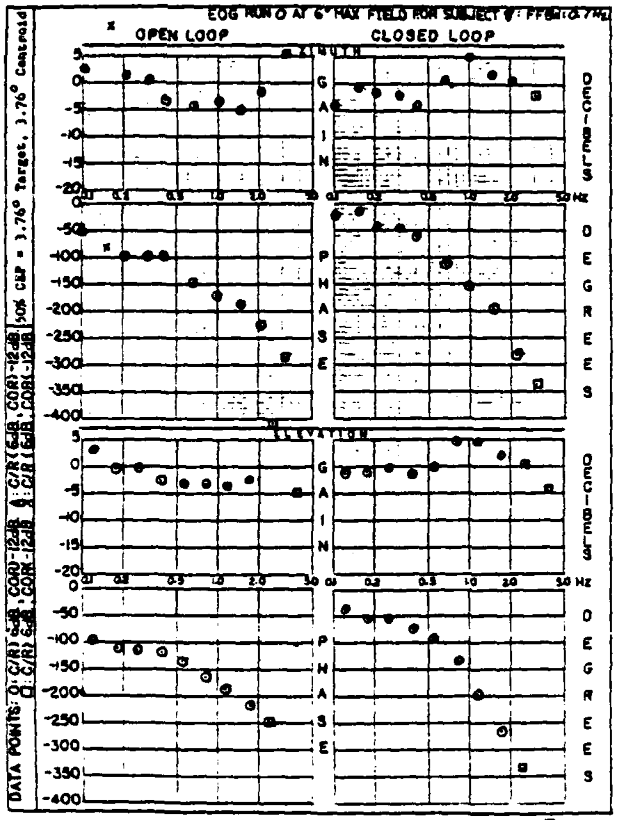
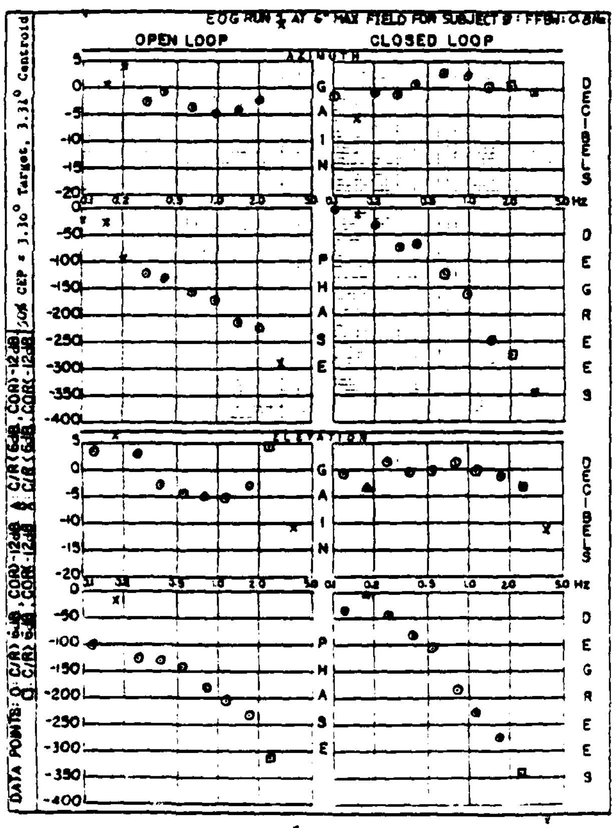


Figure A-9


OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
DATA POINTS: O: C/R) 6dB, COR) -12dB △: C/R (6dB, COR) -12dB
□: C/R) 6dB, COR(-12dB X: C/R (6dB, COR(-12dB
50% CEP = 3.76° Target, 3.76° Centroid


OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
DATA POINTS: O: C/R) 6dB, COR) -12dB △: C/R (6dB, COR) -12dB
□: C/R) 6dB, COR(-12dB X: C/R (6dB, COR(-12dB
50% CEP = 3.36° Target, 3.32° Centroid

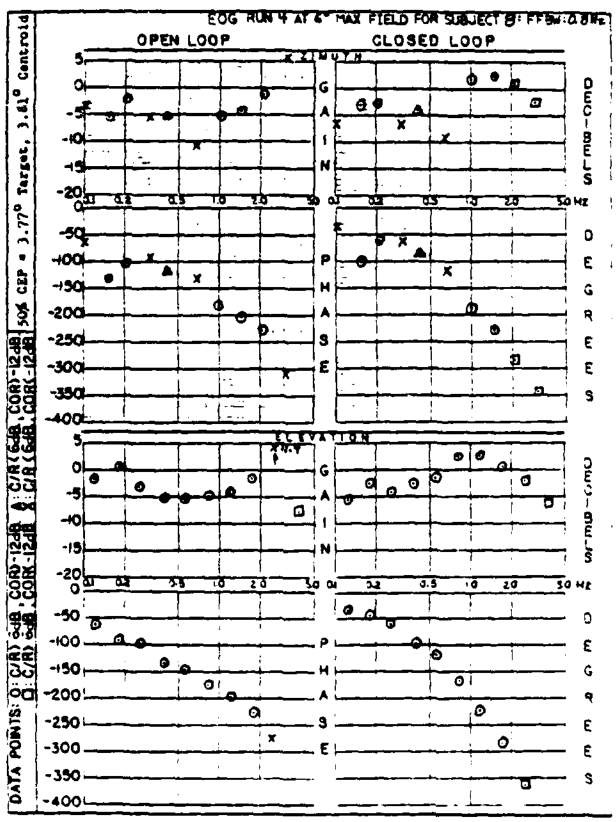

OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
DATA POINTS: O: C/R) 6dB, COR) -12dB △: C/R (6dB, COR) -12dB
□: C/R) 6dB, COR(-12dB X: C/R (6dB, COR(-12dB
50% CEP = 3.77° Target, 3.61° Centroid

Figure A-9 (cont.)

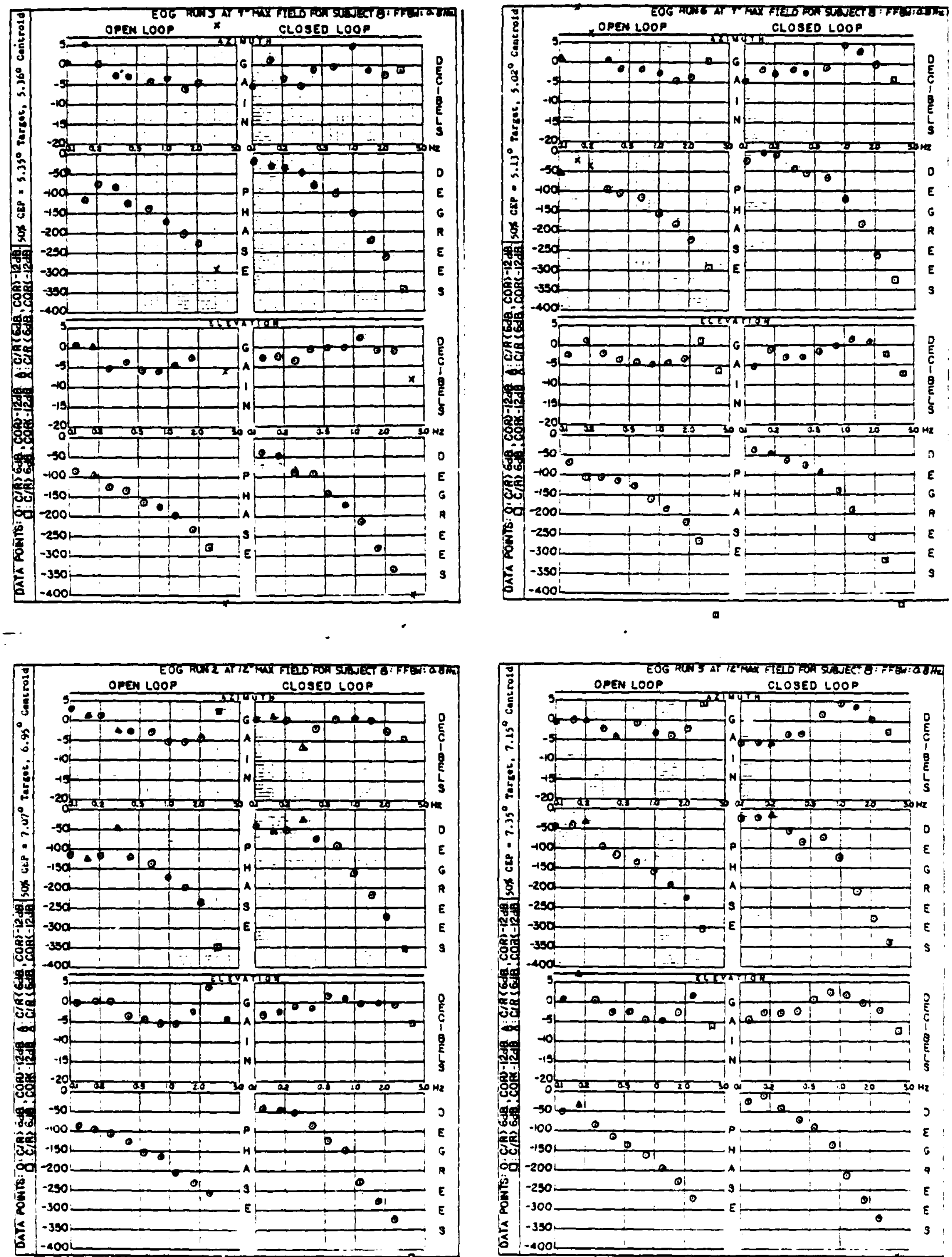


Figure A-10

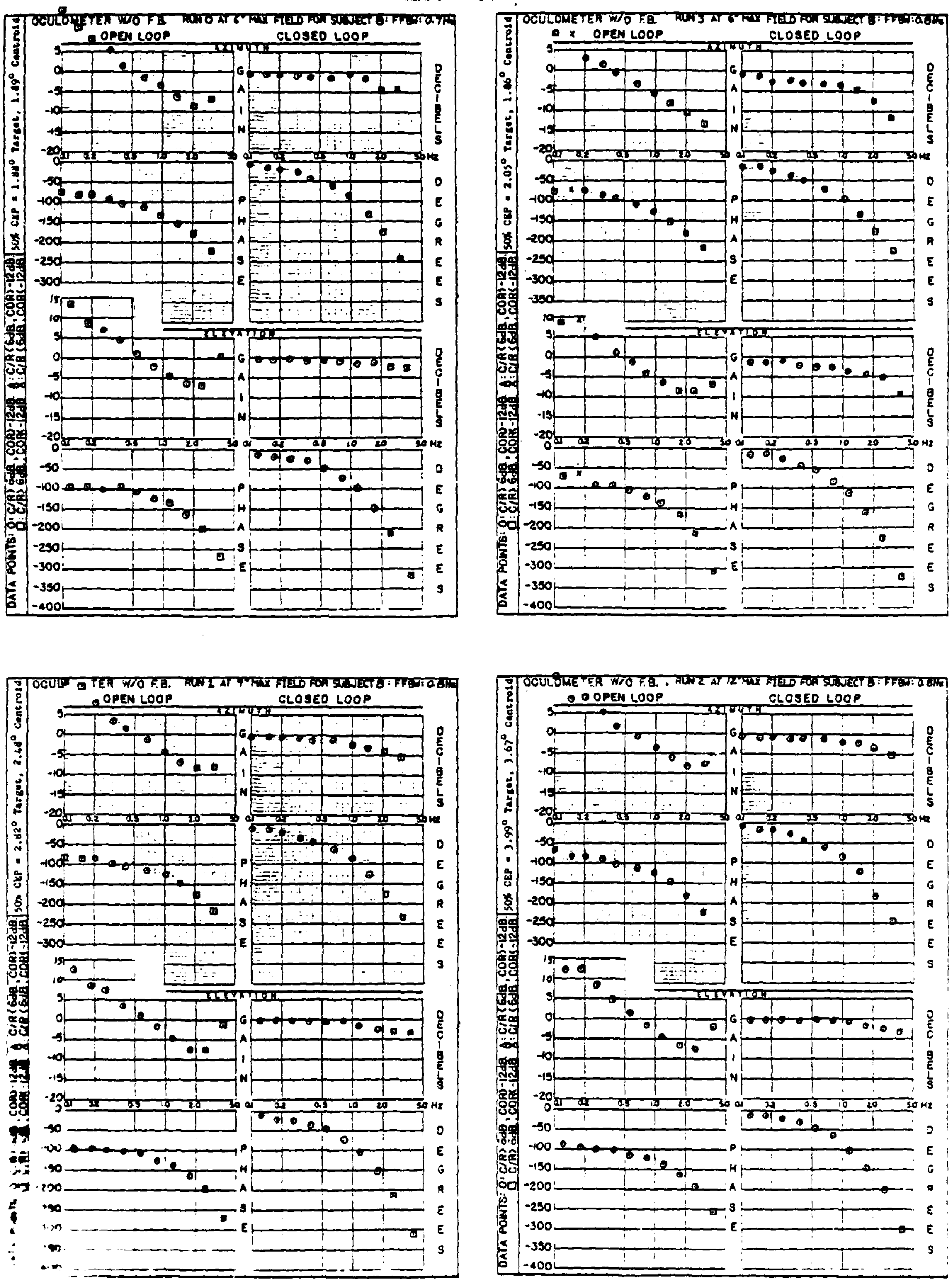
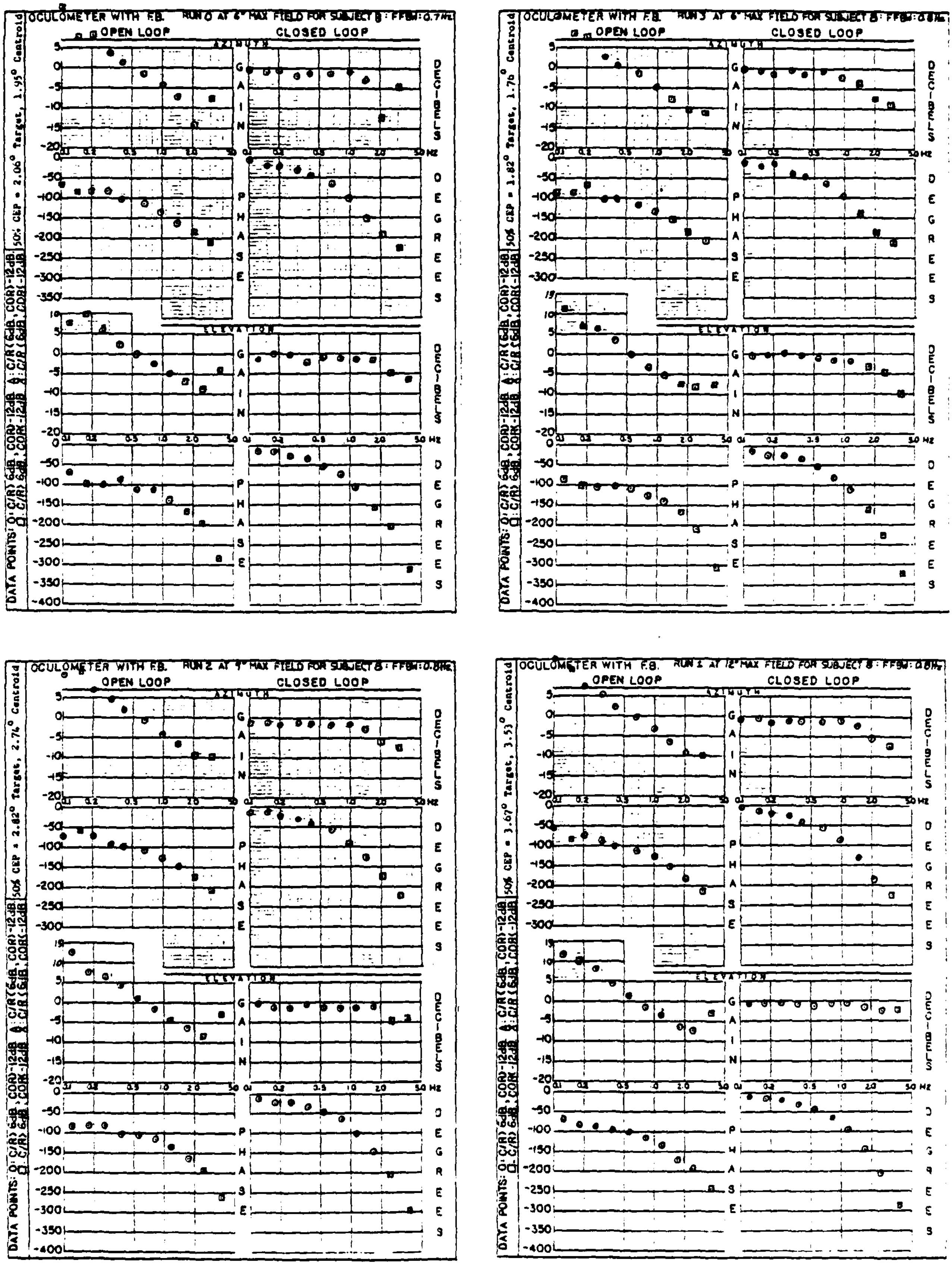


Figure A-11



OCULOMETER WITH F.B. RUN 0 AT 6" MAX FIELD FOR SUBJECT B : FFBW: 0.7Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP = 2.06° Target, 1.95° Centroid
DATA POINTS: O: C/R) 6dB, COR) -12dB; △: C/R) 6dB, COR) -12dB
OCULOMETER WITH F.B. RUN 3 AT 6" MAX FIELD FOR SUBJECT B : FFBW: 0.8Hz
50% CEP = 1.82° Target, 1.76° Centroid
OCULOMETER WITH F.B. RUN 2 AT 9" MAX FIELD FOR SUBJECT B : FFBW: 0.8Hz
50% CEP = 2.82° Target, 2.74° Centroid
OCULOMETER WITH F.B. RUN 1 AT 12" MAX FIELD FOR SUBJECT B : FFBW: 0.8Hz
50% CEP = 3.67° Target, 3.53° Centroid

Figure A-12

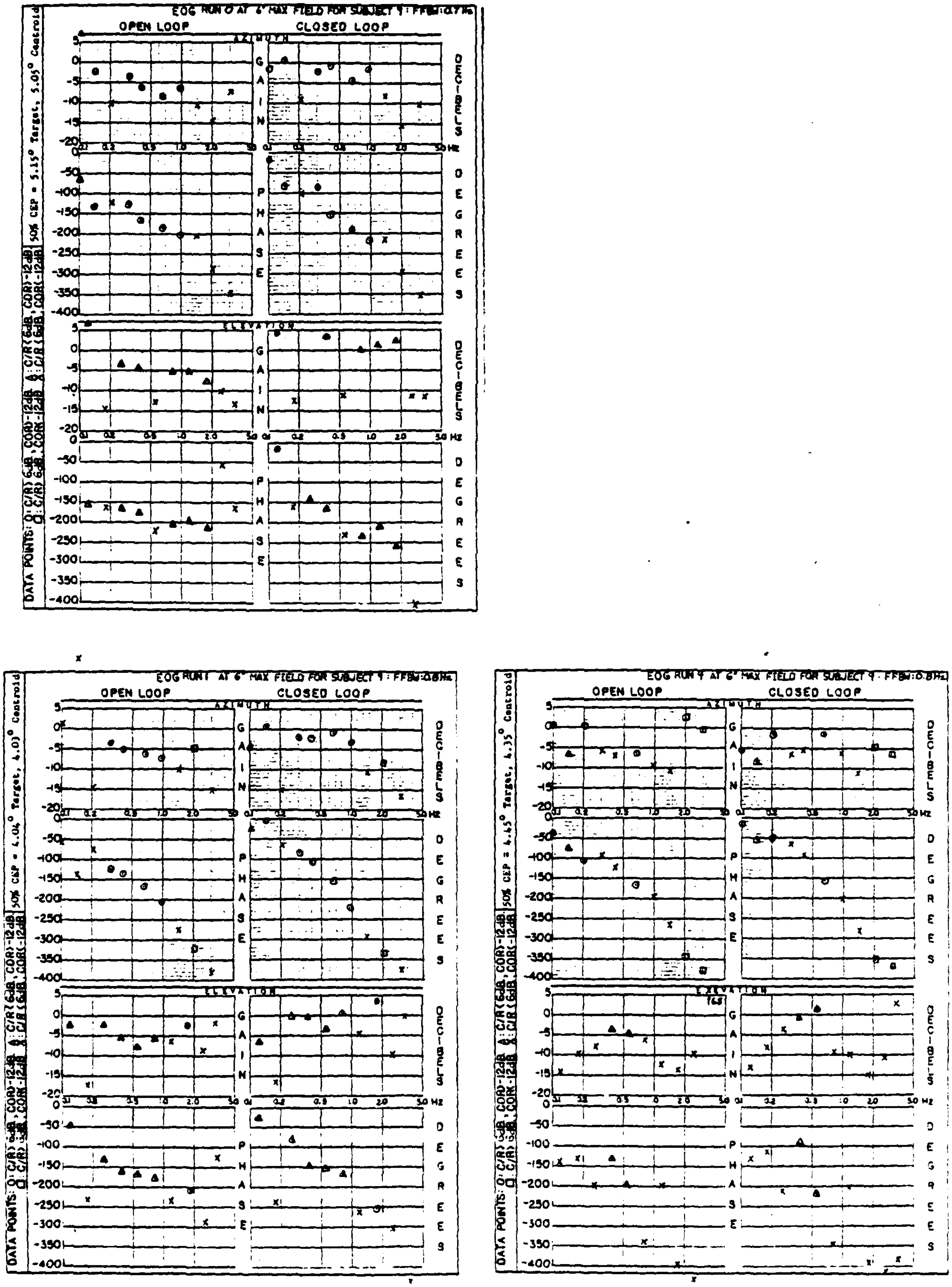
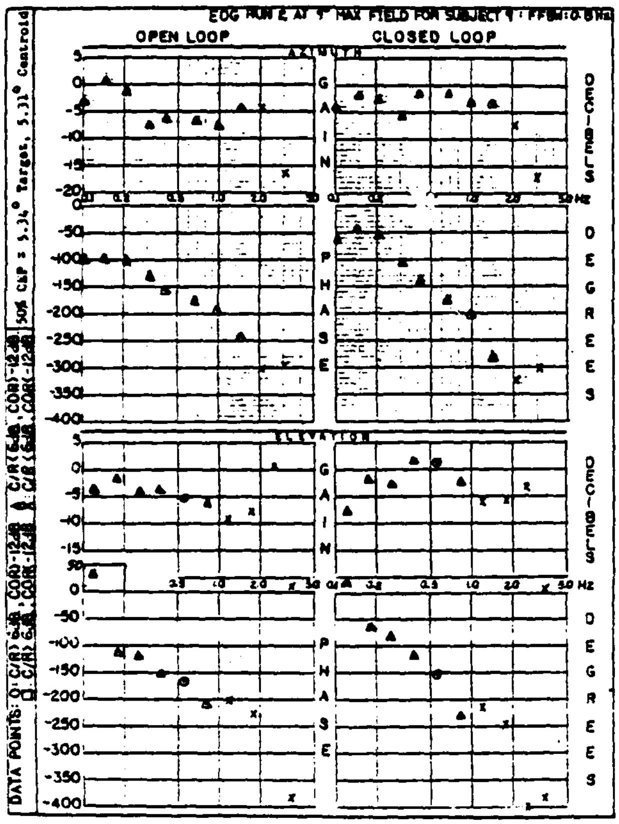
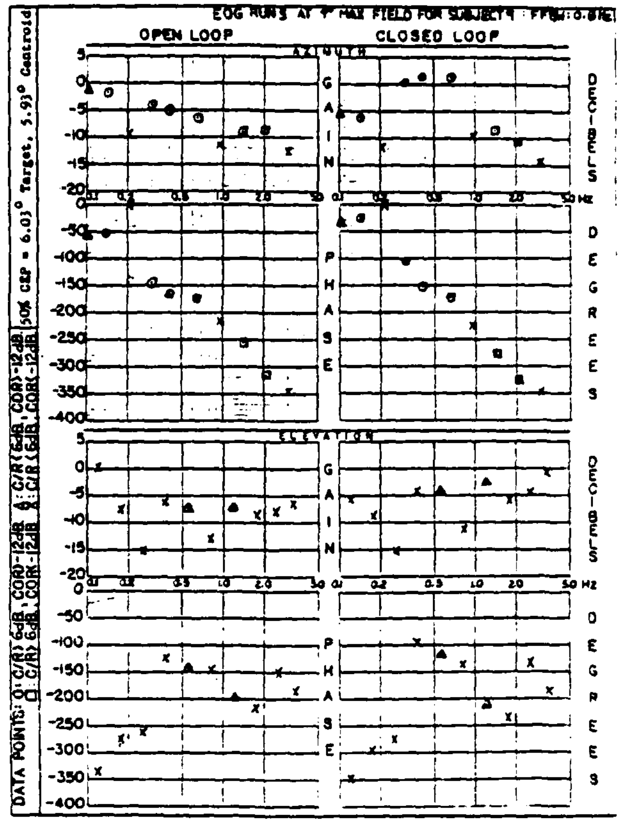
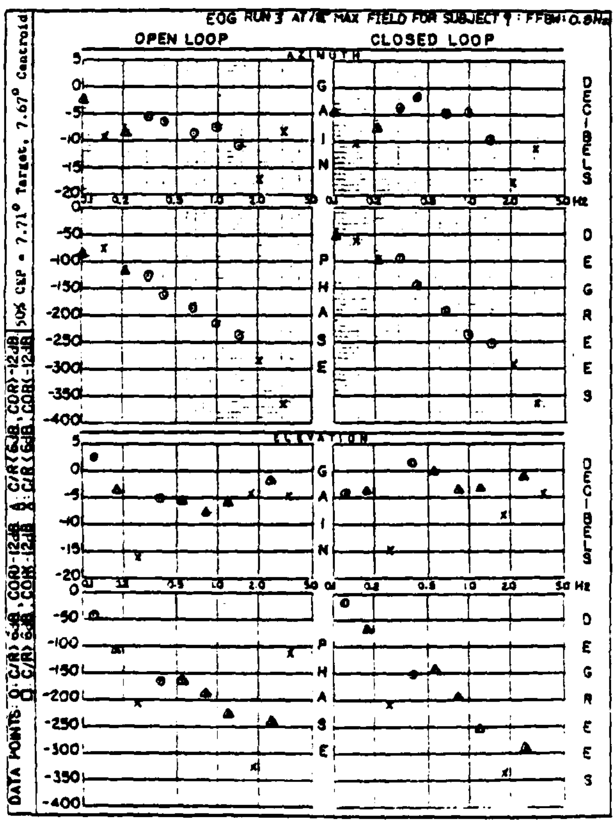

OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES

Figure A-12 (cont.)







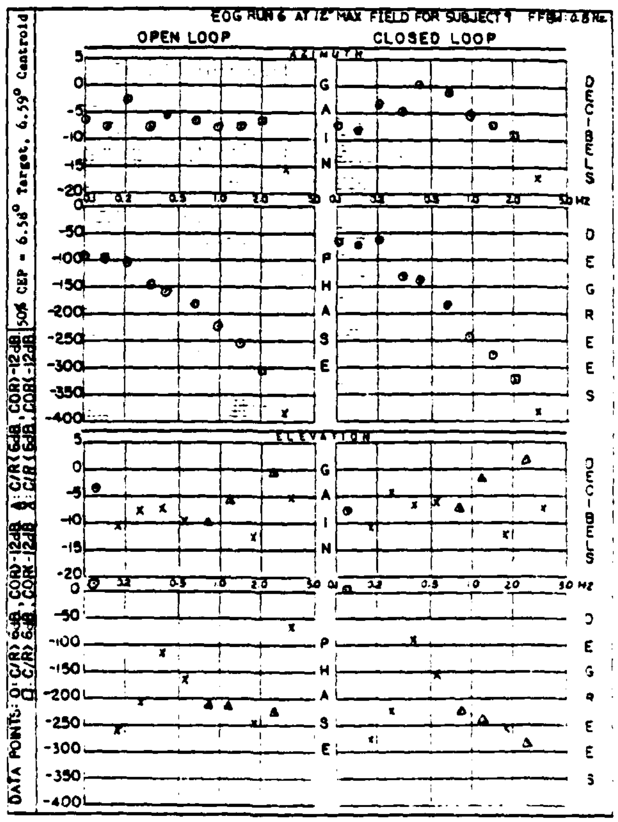
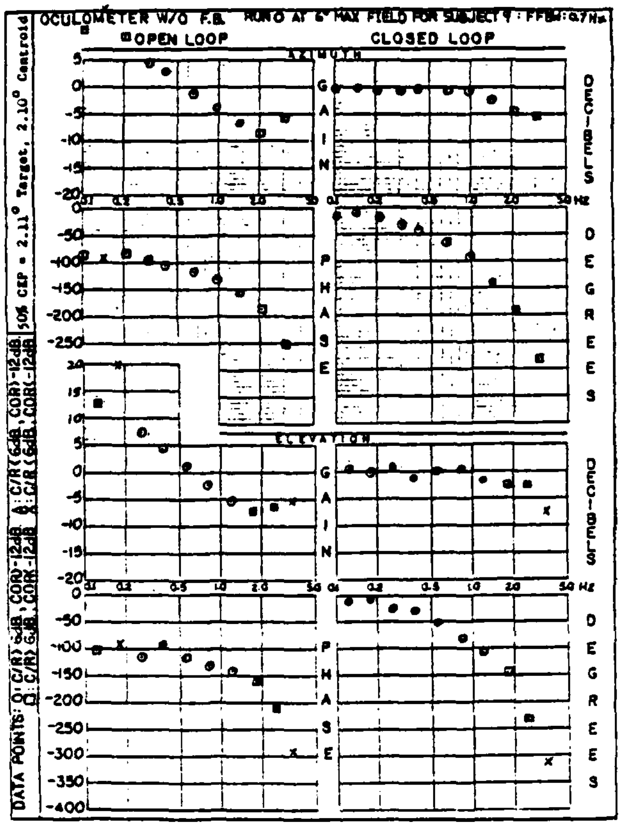
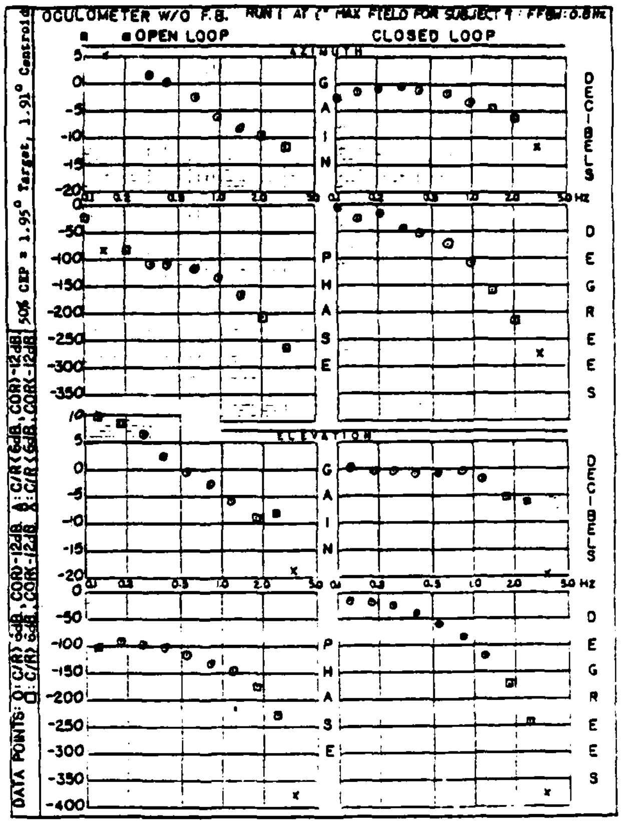
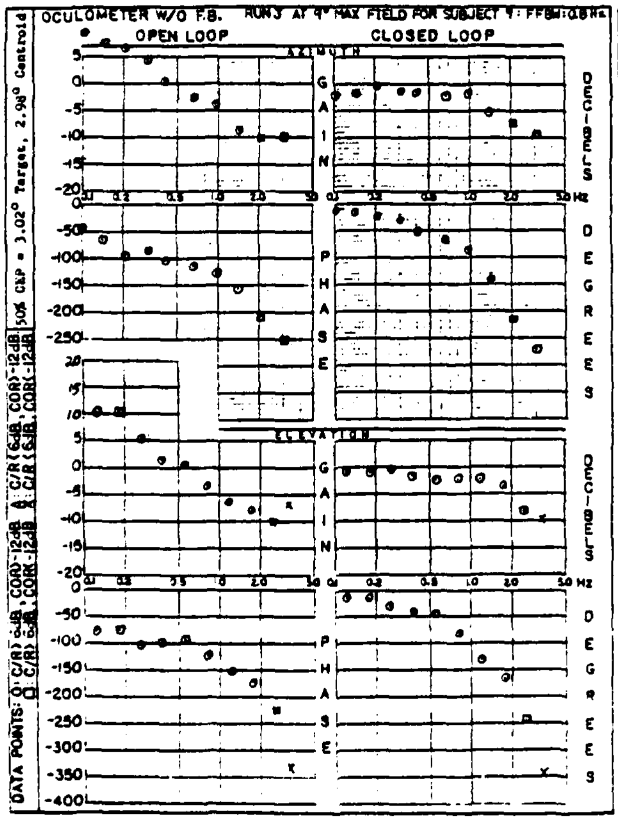


Figure A-13


OCULOMETER W/O F.B. RUN 0 AT 6° MAX FIELD FOR SUBJECT 9 : FFBW: 0.7 Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES


OCULOMETER W/O F.B. RUN 1 AT 6° MAX FIELD FOR SUBJECT 9 : FFBW: 0.8 Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES


OCULOMETER W/O F.B. RUN 3 AT 9° MAX FIELD FOR SUBJECT 9 : FFBW: 0.8 Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES

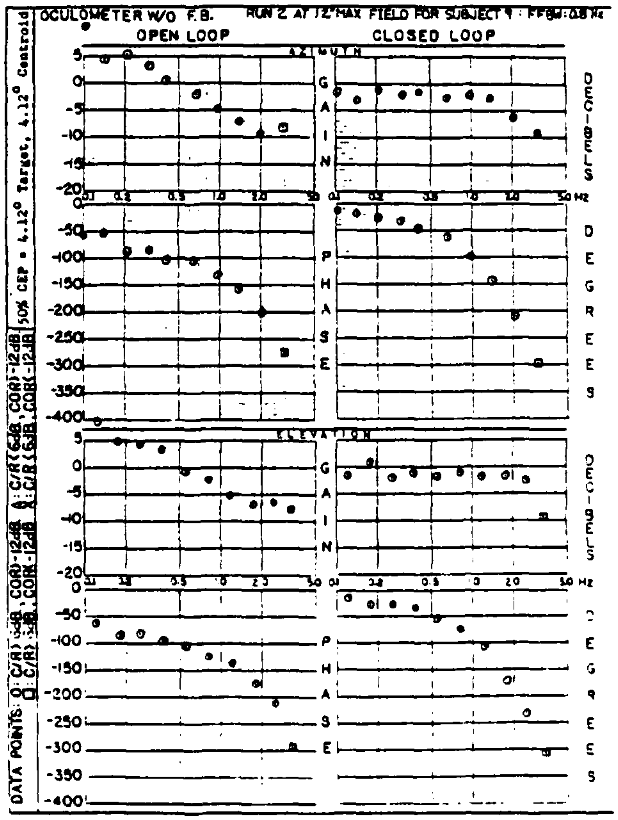

OCULOMETER W/O F.B. RUN 2 AT 12° MAX FIELD FOR SUBJECT 9 : FFBW: 0.8 Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES

Figure A-14

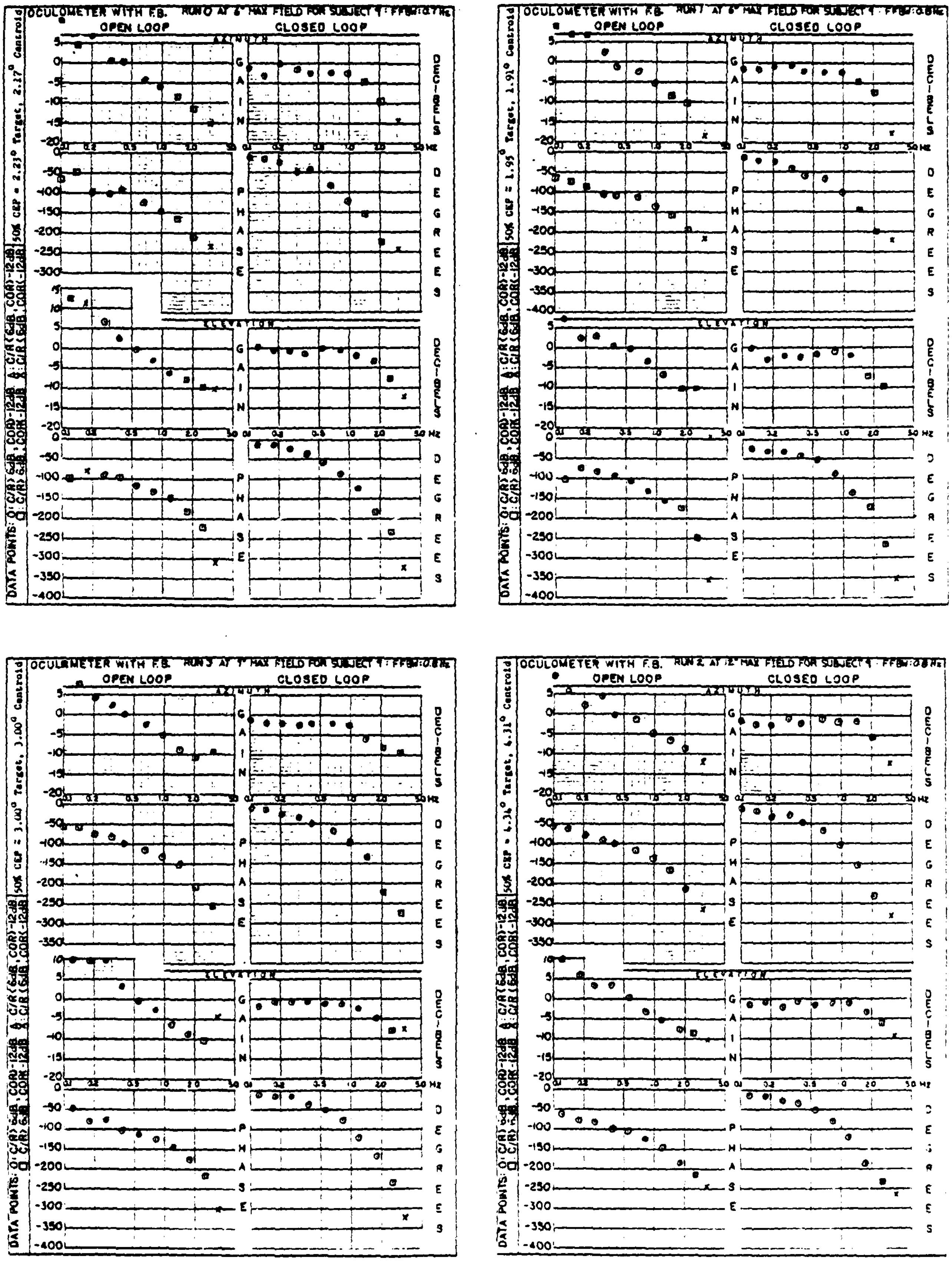
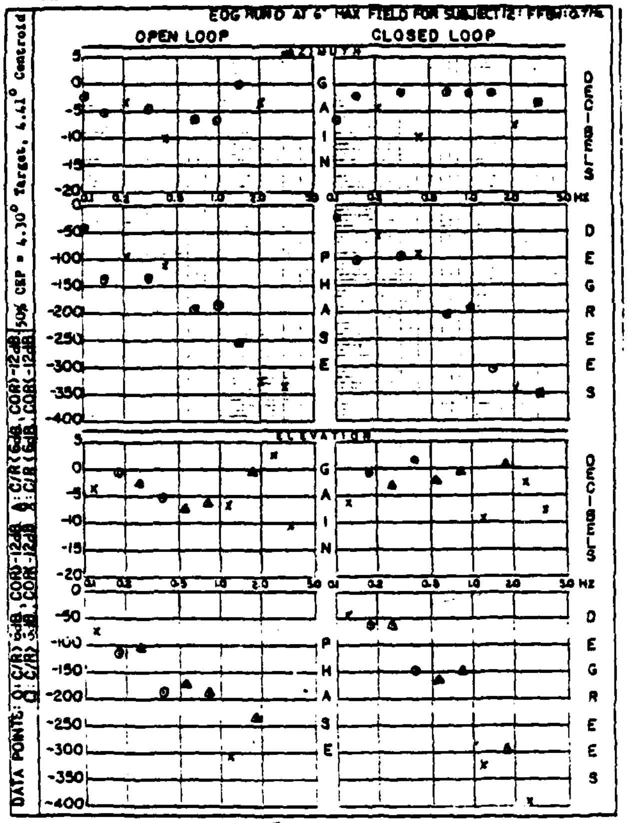
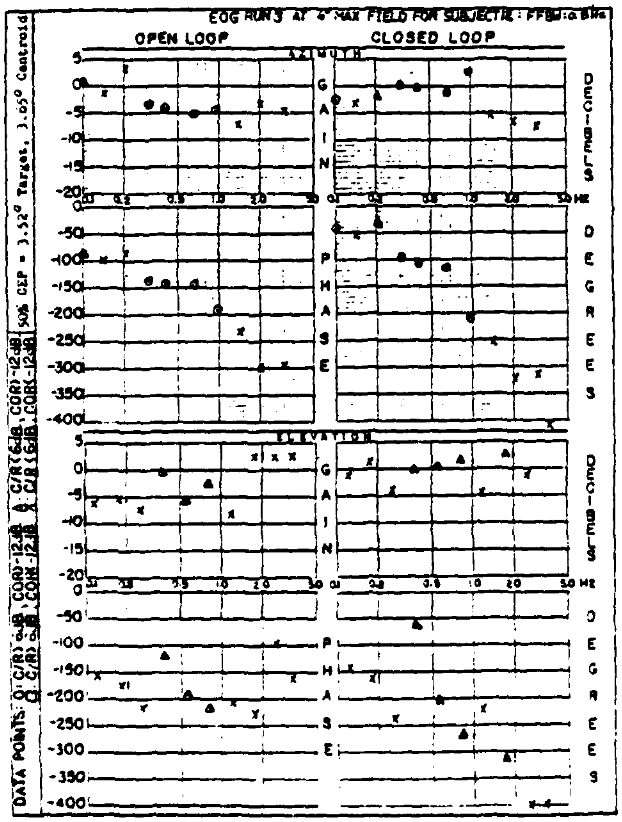

OCULOMETER WITH F.B.
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES

Figure A-15


EOG RUN AT 6' MAX FIELD FOR SUBJECT 12
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
DATA POINTS


EOG RUN 3 AT 6' MAX FIELD FOR SUBJECT 12
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
DATA POINTS

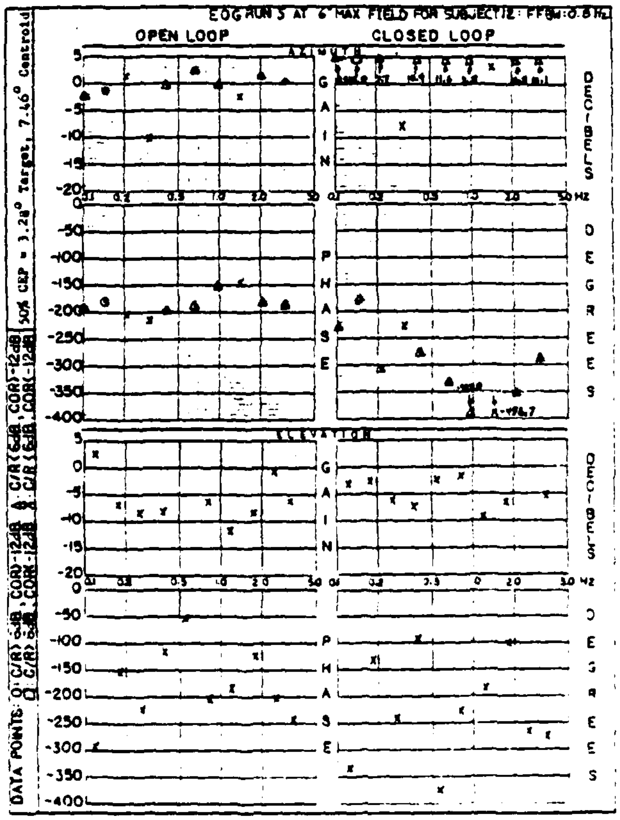

EOG RUN 5 AT 6' MAX FIELD FOR SUBJECT 12
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
DATA POINTS

Figure A-15 (cont.)

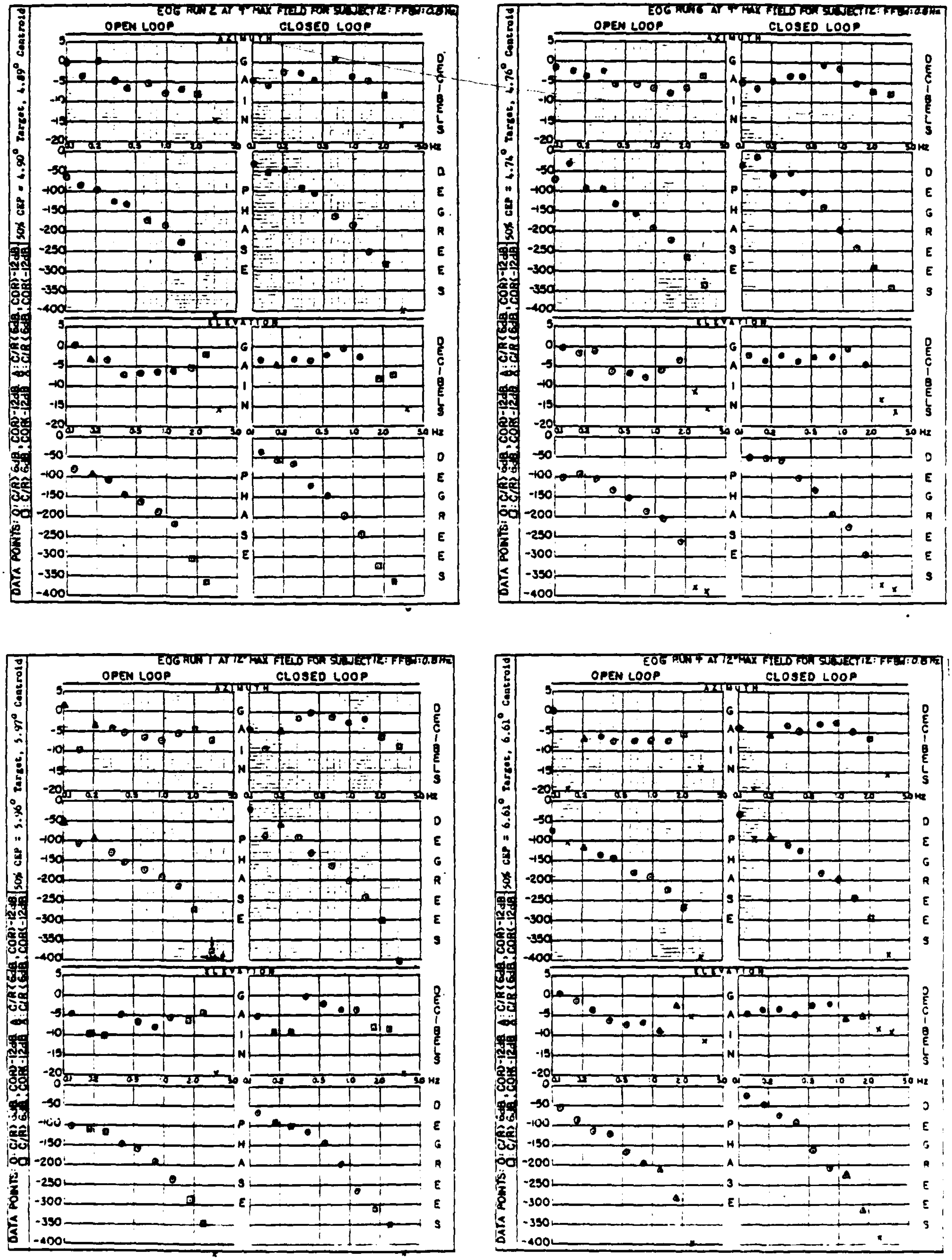


Figure A-16

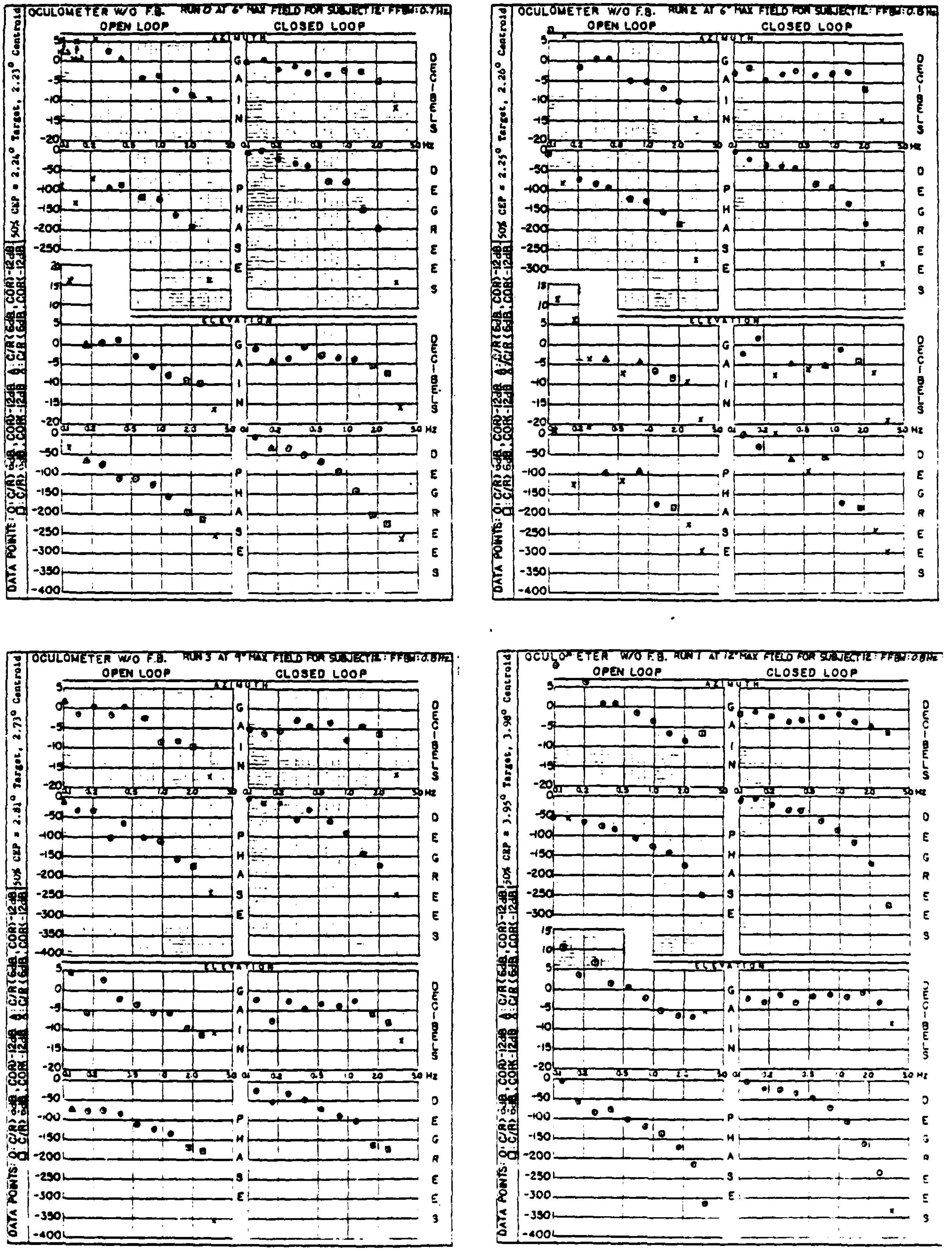
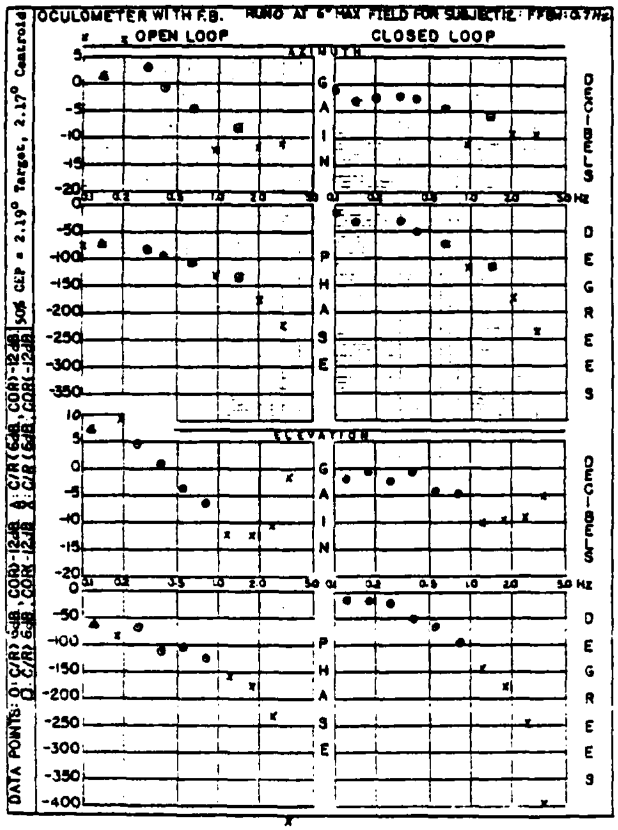
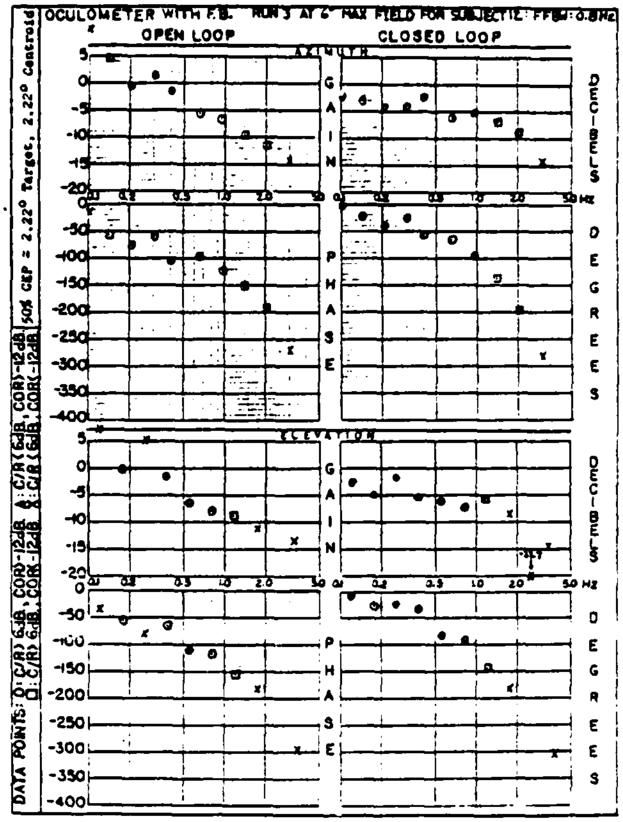
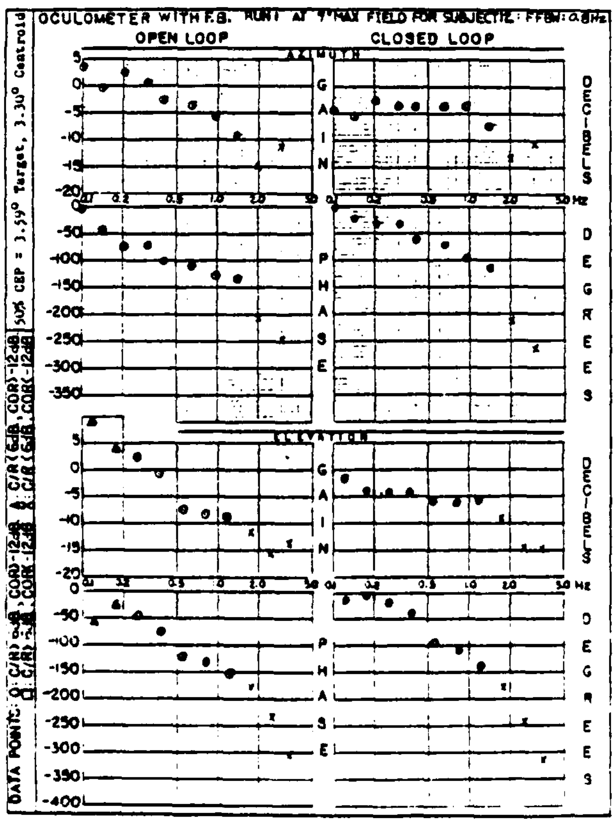
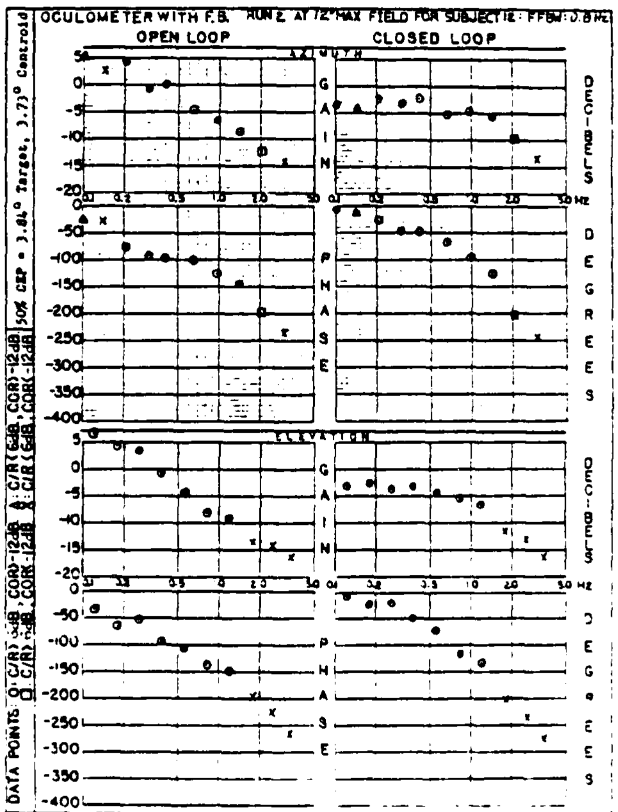

OCULOMETER W/O F.B. RUN 0 AT 6" MAX FIELD FOR SUBJECT 12: FFBW: 0.7Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
50% CEP = 2.24° Target, 2.23° Centroid
OCULOMETER W/O F.B. RUN 2 AT 6" MAX FIELD FOR SUBJECT 12: FFBW: 0.8Hz
50% CEP = 2.25° Target, 2.26° Centroid
OCULOMETER W/O F.B. RUN 3 AT 9" MAX FIELD FOR SUBJECT 12: FFBW: 0.8Hz
50% CEP = 2.81° Target, 2.73° Centroid
OCULOMETER W/O F.B. RUN 1 AT 12" MAX FIELD FOR SUBJECT 12: FFBW: 0.8Hz
50% CEP = 3.95° Target, 3.98° Centroid
GAIN
PHASE
DECIBELS
DEGREES
Hz
DATA POINTS: O: C/R (6dB, COR) -12dB △: C/R (6dB, COR) -12dB
□: C/R (6dB, COR) -12dB ◇: C/R (6dB, COR) -12dB

Figure A-17


OCULOMETER WITH F.B. RUN 0 AT 6° MAX FIELD FOR SUBJECT 12: FFBW: 0.7Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
50% CEP = 2.19° Target, 2.17° Centroid
DATA POINTS: O: C/R(-6dB, COR)-12dB △: C/R(6dB, COR)-12dB □: C/R(-6dB, COR(-12dB


OCULOMETER WITH F.B. RUN 3 AT 6° MAX FIELD FOR SUBJECT 12: FFBW: 0.8Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
50% CEP = 2.22° Target, 2.22° Centroid


OCULOMETER WITH F.B. RUN 1 AT 9° MAX FIELD FOR SUBJECT 12: FFBW: 0.8Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
50% CEP = 3.59° Target, 3.30° Centroid


OCULOMETER WITH F.B. RUN 2 AT 12° MAX FIELD FOR SUBJECT 12: FFBW: 0.8Hz
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
50% CEP = 3.84° Target, 3.73° Centroid

APPENDIX B

FREQUENCY RESPONSE STATISTICS FOR ALL RUNS WITH BREAK FREQUENCY OF 0.8 HERTZ

Presented are the results of the data evaluation for 69 EOG and 36 oculometer tracking runs on subjects 3-14 as described and summarized in Section 6.

Tables B-1 to B-9 present average values, standard deviations, as well as maxima and minima of both gain and phase angle for each frequency. Each of these tables represents an appropriate group of tracking runs of those considered in Section 6. Also shown are the average values and standard deviations of the 50% CEP.

Figures B-1 to B-9 present the plots corresponding to Tables B-1 to B-9 respectively.

Table B-1 (a)

FREQUENCY RESPONSE STATISTICS FOR 24 E O G RUNS AT 6 DEG MAX. FIELD
SUBJECT NO.: 3, 4, 5, 6, 7, 8, 9,12,10,11,13,14,
NUMBER OF RUNS: 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 24RUNS
50% CEP TARGET : AVG.= 3.5 DEG, STD. DEV.= 0.5 DEG, RANGE: 2.4. . .4.9 DEG
50% CEP CENTROID: AVG.= 3.7 DEG, STD. DEV.= 0.9 DEG, RANGE: 2.4. . .7.5 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-3.0	-34.2	3.5	47.2	FAIR	-10.0	-6.5	0.4	8.5	FAIR	-230.5	-81.4	12.9	9.2
0.143	-2.9	-49.6	5.6	40.9	FAIR	-11.4	-8.5	2.7	16.8	FAIR	-180.1	-90.5	-8.7	12.3
0.209	-3.4	-72.7	4.7	63.4	FAIR	-15.3	-8.1	1.3	7.7	FAIR	-306.2	-136.1	-9.3	-12.5
0.308	-4.3	-87.3	3.3	42.3	GOOD	-11.4	-7.6	-1.0	1.5	GOOD	-227.3	-129.6	-45.0	-26.0
0.450	-3.2	-106.5	3.8	45.6	GOOD	-8.1	-7.0	0.6	10.4	GOOD	-275.0	-152.1	-61.0	-60.6
0.659	-2.5	-140.0	4.3	49.1	GOOD	-9.5	-6.8	1.9	11.6	GOOD	-331.8	-189.1	-90.9	-92.3
0.967	-1.1	-189.8	4.2	60.4	GOOD	-11.2	-5.3	3.1	5.8	GOOD	-437.8	-250.2	-129.5	-117.9
1.406	-3.3	-244.4	4.7	52.3	FAIR	-11.1	-8.0	1.5	3.0	FAIR	-456.7	-296.7	-192.1	-166.6
2.055	-3.8	-292.9	6.4	29.3	FAIR	-19.1	-10.2	2.6	16.5	FAIR	-353.9	-322.2	-263.6	-226.3
3.000	-7.1	-343.4	8.9	26.0	ACPT	-30.6	-16.0	1.7	16.1	ACPT	-379.4	-369.4	-317.4	-289.0

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	3.6	-70.6	7.7	53.9	ACPT	-6.9	-4.1	11.3	23.1	ACPT	-228.4	-124.5	-16.7	30.1
0.143	-0.7	-95.1	6.2	47.6	ACPT	-9.8	-6.9	5.5	17.6	ACPT	-197.7	-142.7	-47.5	17.5
0.209	-2.0	-109.6	5.6	38.0	FAIR	-15.6	-7.6	3.6	9.0	FAIR	-203.7	-147.6	-71.6	-52.9
0.308	-4.7	-120.7	3.9	29.5	FAIR	-12.9	-8.7	-0.8	7.1	FAIR	-214.1	-150.2	-91.3	-86.1
0.450	-5.4	-131.9	2.4	25.3	GOOD	-9.9	-7.8	-3.1	-0.2	GOOD	-197.2	-157.2	-106.5	-90.4
0.659	-6.4	-152.2	2.6	20.8	GOOD	-11.0	-9.1	-3.8	2.2	GOOD	-190.4	-173.0	-131.4	-119.8
0.967	-6.4	-178.2	2.5	21.1	GOOD	-12.5	-8.9	-3.9	-0.2	GOOD	-220.0	-199.3	-157.1	-130.8
1.406	-6.9	-211.3	3.0	27.3	FAIR	-12.8	-9.9	-3.9	-2.2	FAIR	-276.6	-238.6	-184.0	-147.1
2.055	-4.2	-252.4	4.9	34.5	FAIR	-19.7	-9.1	0.6	2.7	FAIR	-345.5	-287.0	-217.9	-181.2
3.000	-2.3	-325.4	11.2	52.1	ACPT	-30.4	-13.4	8.9	15.4	ACPT	-402.7	-377.5	-273.3	-188.9

Table B-1 (b)

FREQUENCY RESPONSE STATISTICS FOR 24 E O G RUNS AT 6 DEG MAX. FIELD
SUBJECT NO.: 3, 4, 5, 6, 7, 8, 9,12,10,11,13,14,
NUMBER OF RUNS: 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 24RUNS
50% CEP TARGET : AVG.= 3.5 DEG, STD. DEV.= 0.5 DEG, RANGE: 2.4. . .4.9 DEG
50% CEP CENTROID: AVG.= 3.7 DEG, STD. DEV.= 0.9 DEG, RANGE: 2.4. . .7.5 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-3.1	-71.7	4.5	82.7	FAIR	-15.0	-7.6	1.4	4.2	FAIR	-332.5	-154.5	11.0	-3.2
0.176	-4.8	-97.5	4.9	85.4	ACPT	-19.9	-9.7	0.1	1.1	ACPT	-290.9	-183.0	-12.1	6.3
0.253	-3.4	-115.8	2.9	90.9	ACPT	-9.6	-6.3	-0.5	1.6	ACPT	-347.3	-206.7	-24.9	-24.7
0.374	-2.4	-94.6	3.7	33.8	FAIR	-14.1	-6.1	1.2	3.6	FAIR	-184.8	-128.4	-60.8	-26.4
0.549	-2.2	-138.6	2.6	60.7	FAIR	-8.8	-4.8	0.4	1.2	FAIR	-375.3	-199.2	-77.9	-73.7
0.802	-2.2	-179.9	5.1	59.3	FAIR	-16.3	-7.4	2.9	4.3	FAIR	-344.8	-239.2	-120.6	-80.0
1.165	-3.2	-211.2	5.7	54.5	FAIR	-19.4	-8.9	2.6	4.5	FAIR	-342.3	-265.7	-156.7	-53.9
1.703	-2.2	-259.5	5.3	69.0	FAIR	-15.1	-7.5	3.1	3.5	FAIR	-355.2	-328.6	-190.5	-31.9
2.483	-5.2	-322.7	5.7	78.9	ACPT	-18.1	-10.9	0.4	6.7	ACPT	-508.9	-401.6	-243.8	-58.1
3.626	-6.0	-367.2	6.5	103.6	POOR	-18.6	-12.5	0.4	8.4	POOR	-490.3	-470.8	-263.6	-26.5

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	0.7	-111.5	7.3	56.3	ACPT	-16.1	-6.6	7.9	14.4	ACPT	-293.6	-167.9	-55.2	-49.9
0.176	-3.3	-121.1	7.2	64.5	POOR	-20.7	-10.5	3.9	12.9	POOR	-243.8	-185.6	-56.6	13.9
0.253	-3.1	-139.6	4.8	61.9	ACPT	-9.6	-7.9	1.7	13.2	ACPT	-305.1	-201.6	-77.7	-46.8
0.374	-4.7	-128.4	2.7	29.2	FAIR	-12.5	-7.4	-1.9	-0.2	FAIR	-183.2	-157.6	-99.2	-32.5
0.549	-5.4	-146.3	3.3	28.0	FAIR	-11.4	-8.7	-2.0	7.6	FAIR	-197.9	-174.3	-118.4	-54.6
0.802	-6.6	-184.8	3.1	44.9	FAIR	-17.4	-9.7	-3.4	-2.4	FAIR	-337.4	-229.7	-139.9	-114.3
1.165	-7.2	-199.9	3.6	46.1	FAIR	-19.4	-10.8	-3.6	-3.8	FAIR	-331.4	-246.1	-153.8	-64.0
1.703	-3.6	-224.1	5.5	58.2	FAIR	-13.8	-9.1	2.0	14.7	FAIR	-346.2	-282.3	-165.9	-38.1
2.483	-2.5	-270.5	7.7	90.6	POOR	-17.5	-10.2	5.1	11.4	POOR	-514.1	-361.1	-180.0	-74.0
3.626	-5.2	-272.9	7.2	140.5	POOR	-18.7	-12.4	2.0	7.0	POOR	-484.0	-413.4	-132.5	-73.3

Table B-2 (a)

FREQUENCY RESPONSE STATISTICS FOR 24 E O G RUNS AT 9 DEG MAX. FIELD
SUBJECT NO.: 3, 4, 5, 6, 7, 8, 9,12,10,11,13,14,
NUMBER OF RUNS: 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 24RUNS
50% CEP TARGET : AVG.= 4.7 DEG, STD. DEV.= 0.6 DEG, RANGE: 3.3. . .6.0 DEG
50% CEP CENTROID: AVG.= 4.7 DEG, STD. DEV.= 0.6 DEG, RANGE: 3.4. . .5.9 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-3.7	-38.6	1.6	20.4	GOOD	-6.5	-5.3	-2.1	-0.5	GOOD	-92.2	-59.0	-18.1	-16.0
0.143	-5.1	-45.5	3.1	30.9	FAIR	-12.7	-8.3	-2.0	1.1	FAIR	-123.7	-76.4	-14.6	-0.7
0.209	-5.4	-50.0	3.5	30.1	FAIR	-13.6	-8.9	-1.8	-0.6	FAIR	-138.3	-80.1	-19.9	2.3
0.308	-4.6	-78.3	2.5	30.4	GOOD	-9.6	-7.1	-2.1	0.2	GOOD	-153.6	-108.7	-47.9	-36.5
0.450	-5.0	-102.7	3.8	32.3	GOOD	-14.0	-8.8	-1.2	1.4	GOOD	-171.9	-135.0	-70.4	-59.2
0.659	-3.5	-126.2	3.9	34.6	GOOD	-16.1	-7.4	0.4	1.7	GOOD	-205.9	-160.8	-91.6	-68.1
0.967	-2.4	-169.1	4.1	36.0	GOOD	-9.7	-6.5	1.7	4.9	GOOD	-243.3	-205.1	-133.1	-105.2
1.406	-2.7	-224.5	3.9	29.3	GOOD	-10.9	-6.7	1.2	3.0	GOOD	-281.2	-253.8	-195.3	-164.5
2.055	-4.7	-286.8	4.4	22.3	GOOD	-11.7	-9.1	-0.4	0.3	GOOD	-329.2	-309.1	-264.5	-238.9
3.000	-7.9	-351.4	5.8	24.8	FAIR	-17.5	-13.7	-2.1	-0.9	FAIR	-402.6	-376.3	-326.6	-301.5

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	0.4	-75.6	3.4	24.0	FAIR	-5.8	-3.0	3.8	8.1	FAIR	-126.3	-99.6	-51.6	-42.0
0.143	-2.0	-74.5	5.5	38.7	FAIR	-10.5	-7.5	3.5	14.1	FAIR	-144.8	-113.2	-35.7	-1.6
0.209	-2.7	-82.7	5.2	31.0	FAIR	-14.9	-7.9	2.5	7.3	FAIR	-145.2	-113.7	-51.6	3.0
0.308	-4.7	-110.4	2.9	25.3	GOOD	-10.8	-7.6	-1.8	0.8	GOOD	-162.5	-135.7	-85.1	-55.3
0.450	-6.7	-128.4	3.3	24.3	GOOD	-15.0	-10.0	-3.4	-1.5	GOOD	-174.4	-152.7	-104.1	-89.7
0.659	-6.8	-146.5	2.9	23.5	GOOD	-17.1	-9.7	-4.0	-1.6	GOOD	-196.7	-170.0	-123.0	-111.6
0.967	-7.1	-174.8	2.2	23.0	GOOD	-11.6	-9.3	-4.9	-2.8	GOOD	-225.1	-197.8	-151.7	-127.3
1.406	-6.8	-206.7	2.3	21.6	GOOD	-13.0	-9.1	-4.5	-4.0	GOOD	-256.8	-228.3	-185.1	-167.9
2.055	-5.1	-253.1	3.6	27.9	GOOD	-12.6	-8.7	-1.6	-1.2	GOOD	-318.2	-281.0	-225.1	-220.9
3.000	-2.5	-324.3	9.6	70.3	ACPT	-16.6	-12.1	7.1	11.0	ACPT	-409.9	-394.6	-254.0	-54.9

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Table B-2 (b)

FREQUENCY RESPONSE STATISTICS FOR 24 E O G RUNS AT 9 DEG MAX. FIELD
SUBJECT NO.: 3, 4, 5, 6, 7, 8, 9,12,10,11,13,14,
NUMBER OF RUNS: 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 24RUNS
50% CEP TARGET : AVG.= 4.7 DEG, STD. DEV.= 0.6 DEG, RANGE: 3.3. . .6.0 DEG
50% CEP CENTROID: AVG.= 4.7 DEG, STD. DEV.= 0.6 DEG, RANGE: 3.4. . .5.9 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-3.8	-51.6	2.8	70.5	GOOD	-12.3	-6.6	-1.0	0.5	GOOD	-349.0	-122.1	18.8	18.4
0.176	-2.9	-73.3	2.6	85.3	FAIR	-8.7	-5.4	-0.3	2.6	FAIR	-382.9	-158.6	11.9	-3.8
0.253	-5.0	-91.6	3.3	72.7	FAIR	-15.3	-8.3	-1.7	-0.7	FAIR	-312.6	-164.3	-18.9	-18.8
0.374	-2.8	-104.0	3.0	34.2	GOOD	-10.7	-5.7	0.2	1.9	GOOD	-195.4	-138.2	-69.8	-58.9
0.549	-2.7	-122.1	2.7	37.9	GOOD	-9.5	-5.4	-0.0	1.4	GOOD	-223.2	-160.0	-84.2	-46.7
0.802	-2.3	-164.4	3.7	44.8	FAIR	-11.3	-6.0	1.3	3.3	FAIR	-266.1	-209.2	-119.6	-70.6
1.165	-2.4	-211.4	4.4	30.0	GOOD	-16.7	-6.8	2.0	3.3	GOOD	-287.9	-241.5	-181.4	-160.7
1.703	-3.3	-271.1	4.8	42.5	FAIR	-14.1	-8.1	1.5	4.6	FAIR	-377.1	-313.6	-228.6	-176.9
2.483	-6.2	-324.7	5.1	69.8	ACPT	-14.6	-11.3	-1.1	1.5	ACPT	-412.9	-394.4	-254.9	-133.5
3.626	-8.5	-364.1	7.0	81.0	POOR	-23.8	-15.5	-1.4	2.7	POOR	-454.7	-445.0	-283.1	-149.0

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	0.4	-97.9	5.0	76.5	FAIR	-10.8	-4.6	5.4	10.1	FAIR	-337.7	-174.4	-21.4	30.5
0.176	0.1	-100.4	4.8	48.2	ACPT	-7.8	-4.6	4.9	11.1	ACPT	-275.8	-148.7	-52.2	-9.8
0.253	-4.3	-119.0	4.4	56.6	FAIR	-15.4	-8.7	0.1	4.3	FAIR	-277.5	-175.6	-62.5	-28.8
0.374	-5.1	-135.5	2.8	22.6	GOOD	-12.8	-7.9	-2.4	-1.7	GOOD	-191.9	-158.1	-112.9	-97.4
0.549	-5.9	-144.9	2.3	26.2	GOOD	-10.2	-8.2	-3.6	0.8	GOOD	-209.8	-171.2	-118.7	-85.8
0.802	-6.7	-171.5	2.1	29.6	FAIR	-13.0	-8.8	-4.7	-4.1	FAIR	-239.9	-201.1	-141.9	-95.0
1.165	-7.0	-199.5	2.7	21.8	GOOD	-17.7	-9.7	-4.3	-4.0	GOOD	-259.3	-221.3	-177.6	-168.9
1.703	-5.4	-242.0	3.1	47.7	FAIR	-13.4	-8.4	-2.3	-0.7	FAIR	-383.1	-289.7	-194.3	-178.4
2.483	-4.0	-294.3	6.3	92.5	ACPT	-14.0	-10.4	2.3	6.9	ACPT	-441.7	-386.8	-201.8	-62.5
3.626	-6.7	-338.5	8.5	129.0	POOR	-24.4	-15.2	1.7	11.4	POOR	-546.2	-467.5	-209.5	-94.7

Table B-3 (a)

FREQUENCY RESPONSE STATISTICS FOR 21 E O G RUNS AT 12 DEG MAX. FIELD
SUBJECT NO.: 3, 4, 5, 6, 7, 8, 9,12,10,11,13,14,
NUMBER OF RUNS: 2+ 1+ 1+ 1+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 21RUNS
50% CEP TARGET : AVG.= 6.2 DEG, STD. DEV.= 1.0 DEG, RANGE: 3.8. . .7.7 DEG
50% CEP CENTROID: AVG.= 6.2 DEG, STD. DEV.= 1.0 DEG, RANGE: 3.7. . .7.7 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-5.0	-42.6	3.0	29.4	GOOD	-11.9	-8.0	-2.0	0.4	GOOD	-146.9	-72.0	-13.3	-13.3
0.143	-6.5	-61.2	4.6	51.3	FAIR	-19.5	-11.1	-1.8	1.2	FAIR	-238.4	-112.5	-9.9	-12.2
0.209	-4.5	-58.6	2.5	26.4	FAIR	-10.3	-7.1	-2.0	0.1	FAIR	-131.7	-85.1	-32.2	-17.6
0.308	-4.4	-79.4	2.3	29.8	GOOD	-8.5	-6.7	-2.1	-0.6	GOOD	-153.7	-109.2	-49.6	-28.7
0.450	-3.8	-104.3	2.8	33.9	GOOD	-12.5	-6.6	-1.0	0.2	GOOD	-195.8	-138.3	-70.4	-56.1
0.659	-2.9	-130.3	2.8	38.1	GOOD	-8.8	-5.7	-0.1	2.8	GOOD	-203.1	-168.4	-92.2	-73.5
0.967	-2.5	-170.3	3.1	35.9	GOOD	-8.0	-5.7	0.6	4.1	GOOD	-241.9	-206.1	-134.4	-118.0
1.406	-3.0	-222.9	3.7	25.9	GOOD	-10.0	-6.7	0.7	3.8	GOOD	-279.3	-248.8	-197.0	-174.1
2.055	-4.7	-284.4	4.5	21.1	GOOD	-17.6	-9.3	-0.2	1.7	GOOD	-323.6	-305.5	-263.3	-237.2
3.000	-8.0	-358.6	5.4	21.6	FAIR	-17.0	-13.4	-2.5	-1.1	FAIR	-407.7	-380.2	-337.0	-324.3

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-1.2	-75.1	5.2	29.5	GOOD	-11.1	-6.4	4.0	6.2	GOOD	-155.7	-104.6	-45.6	-18.9
0.143	-3.8	-88.6	6.6	43.9	FAIR	-19.7	-10.4	2.7	6.4	FAIR	-231.6	-132.5	-44.8	-38.4
0.209	-2.9	-94.0	3.7	27.2	FAIR	-12.1	-6.6	0.8	3.9	FAIR	-142.4	-121.1	-66.8	-27.5
0.308	-4.6	-112.5	3.2	24.1	GOOD	-9.3	-7.8	-1.4	2.0	GOOD	-162.5	-136.6	-88.3	-48.7
0.450	-5.9	-131.0	2.3	25.6	GOOD	-13.1	-8.2	-3.5	-2.9	GOOD	-190.3	-156.6	-105.4	-88.3
0.659	-6.3	-150.7	2.1	23.6	GOOD	-9.8	-8.5	-4.2	-0.9	GOOD	-195.3	-174.3	-127.1	-113.3
0.967	-7.1	-175.2	1.7	22.2	GOOD	-10.9	-8.8	-5.4	-3.2	GOOD	-221.2	-197.4	-153.0	-136.3
1.406	-7.1	-206.0	2.2	19.7	GOOD	-12.4	-9.2	-4.9	-4.0	GOOD	-254.7	-225.7	-186.3	-175.8
2.055	-5.2	-250.2	4.0	24.1	GOOD	-17.2	-9.2	-1.2	-1.0	GOOD	-307.5	-274.3	-226.1	-221.5
3.000	-2.5	-350.9	8.9	39.5	FAIR	-15.8	-11.4	6.4	9.4	FAIR	-426.8	-390.4	-311.3	-278.5

Table B-3 (b)

FREQUENCY RESPONSE STATISTICS FOR 21 E O G RUNS AT 12 DEG MAX. FIELD
SUBJECT NO.: 3, 4, 5, 6, 7, 8, 9,12,10,11,13,14,
NUMBER OF RUNS: 2+ 1+ 1+ 1+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 21RUNS
50% CEP TARGET : AVG.= 6.2 DEG, STD. DEV.= 1.0 DEG, RANGE: 3.8. . .7.7 DEG
50% CEP CENTROID: AVG.= 6.2 DEG, STD. DEV.= 1.0 DEG, RANGE: 3.7. . .7.7 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-4.0	-51.2	2.7	71.2	GOOD	-12.4	-6.7	-1.3	-0.8	GOOD	-351.0	-122.5	20.0	-6.9
0.176	-4.7	-65.4	3.0	56.2	FAIR	-11.7	-7.6	-1.7	0.6	FAIR	-277.0	-121.6	-9.2	-10.6
0.253	-4.7	-81.9	3.7	55.3	FAIR	-14.8	-8.4	-1.0	0.5	FAIR	-221.6	-137.3	-26.6	-26.1
0.374	-2.2	-92.8	2.4	27.5	GOOD	-7.2	-4.6	0.1	1.5	GOOD	-163.2	-120.3	-65.3	-48.7
0.549	-2.9	-118.8	2.8	35.9	GOOD	-8.8	-5.7	-0.1	1.7	GOOD	-200.8	-154.7	-83.0	-40.1
0.802	-1.9	-157.3	2.7	39.9	GOOD	-7.1	-4.6	0.8	2.7	GOOD	-249.3	-197.2	-117.5	-93.5
1.165	-2.7	-205.5	3.3	37.2	GOOD	-10.0	-6.1	0.6	2.3	GOOD	-274.7	-242.7	-168.3	-132.2
1.703	-5.1	-271.4	6.8	33.9	FAIR	-25.5	-11.8	1.7	4.0	FAIR	-338.8	-305.3	-237.5	-190.1
2.483	-5.3	-324.9	5.0	47.5	FAIR	-17.6	-10.3	-0.3	1.9	FAIR	-412.2	-372.4	-277.4	-184.3
3.626	-8.9	-379.5	6.3	100.8	POOR	-22.6	-15.2	-2.7	1.1	POOR	-499.4	-480.3	-278.7	-130.2

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	1.3	-86.2	5.8	63.5	FAIR	-13.2	-4.6	7.1	16.0	FAIR	-345.1	-149.7	-22.7	-20.5
0.176	-2.2	-96.8	5.5	47.0	ACPT	-10.6	-7.7	3.4	8.8	ACPT	-260.0	-143.8	-49.8	-35.2
0.253	-4.0	-113.8	4.9	40.6	FAIR	-16.1	-8.9	1.0	4.2	FAIR	-205.9	-154.3	-73.2	-55.1
0.374	-4.2	-128.7	2.3	18.3	GOOD	-8.8	-6.5	-1.9	1.0	GOOD	-170.8	-147.0	-110.3	-102.5
0.549	-6.0	-142.2	2.1	28.1	GOOD	-9.5	-8.1	-4.0	-0.6	GOOD	-193.7	-170.2	-114.1	-58.0
0.802	-6.5	-170.2	1.4	25.1	GOOD	-9.7	-7.9	-5.1	-4.4	GOOD	-228.5	-195.3	-145.1	-125.0
1.165	-6.9	-196.1	2.1	24.1	GOOD	-12.4	-9.0	-4.8	-4.6	GOOD	-241.8	-220.2	-172.0	-148.1
1.703	-6.7	-243.0	5.5	37.0	FAIR	-25.5	-12.2	-1.2	-0.8	FAIR	-326.0	-280.0	-206.0	-186.1
2.483	-1.6	-296.0	9.7	62.6	ACPT	-16.8	-11.3	8.1	32.6	ACPT	-428.8	-358.6	-233.4	-182.6
3.626	-8.0	-315.2	7.3	155.1	POOR	-23.2	-15.3	-0.7	5.1	POOR	-509.5	-470.4	-160.1	-67.0

Figure B-1

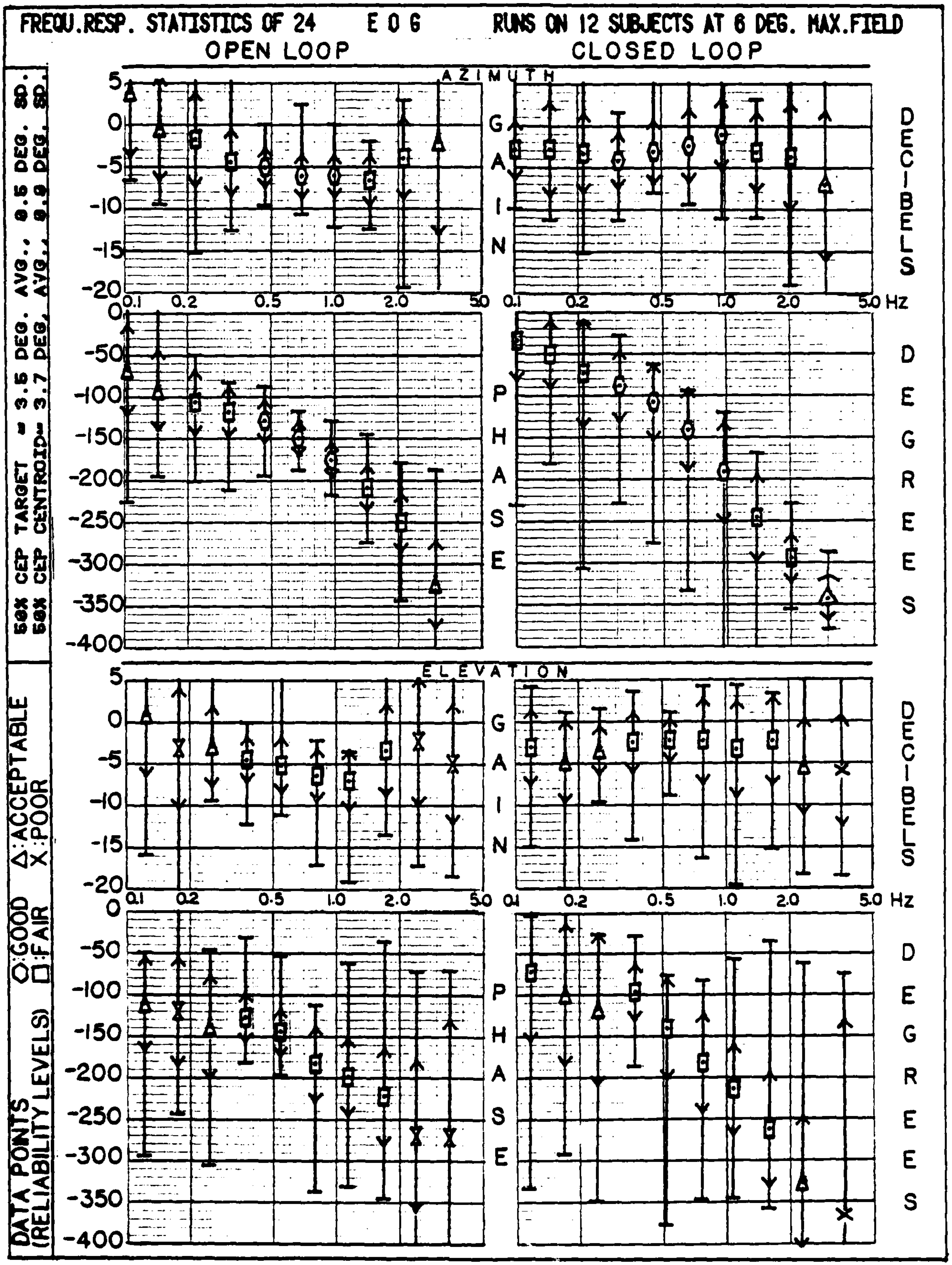

FREQU.RESP. STATISTICS OF 24 E O G RUNS ON 12 SUBJECTS AT 6 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 3.5 DEG. AVG., 9.5 DEG. SD.
50% CEP CENTROID= 3.7 DEG. AVG., 9.9 DEG. SD.
DATA PONTS (RELIABILITY LEVELS)
○:GOOD □:FAIR △:ACCEPTABLE X:POOR

Figure B-2

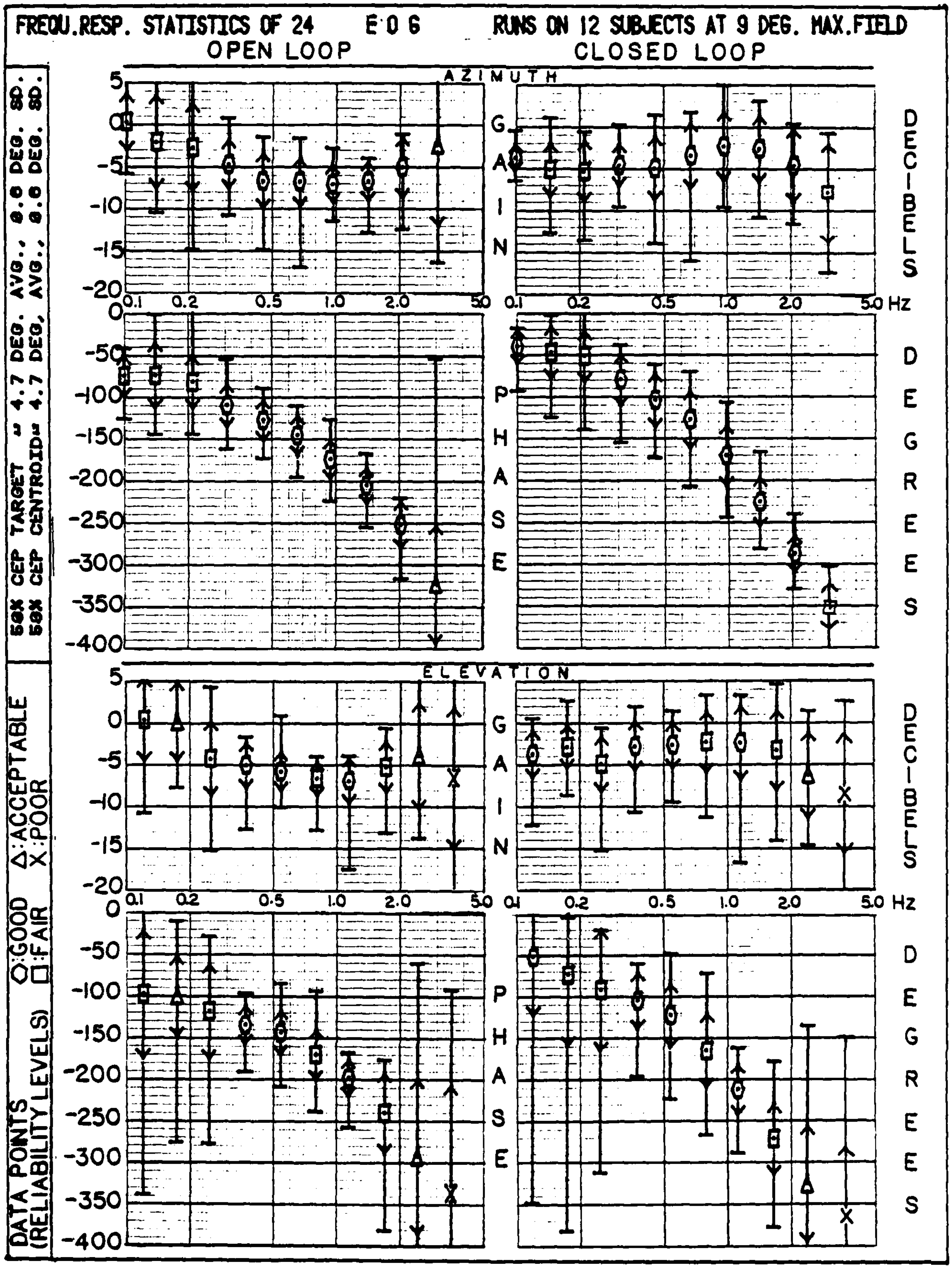

FREQU.RESP. STATISTICS OF 24 E O G RUNS ON 12 SUBJECTS AT 9 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET " 4.7 DEG. AVG., 8.8 DEG. SD.
50% CEP CENTROID" 4.7 DEG, AVG., 8.8 DEG. SD.
DATA POINTS (RELIABILITY LEVELS) ○:GOOD □:FAIR △:ACCEPTABLE X:POOR

Figure B-3

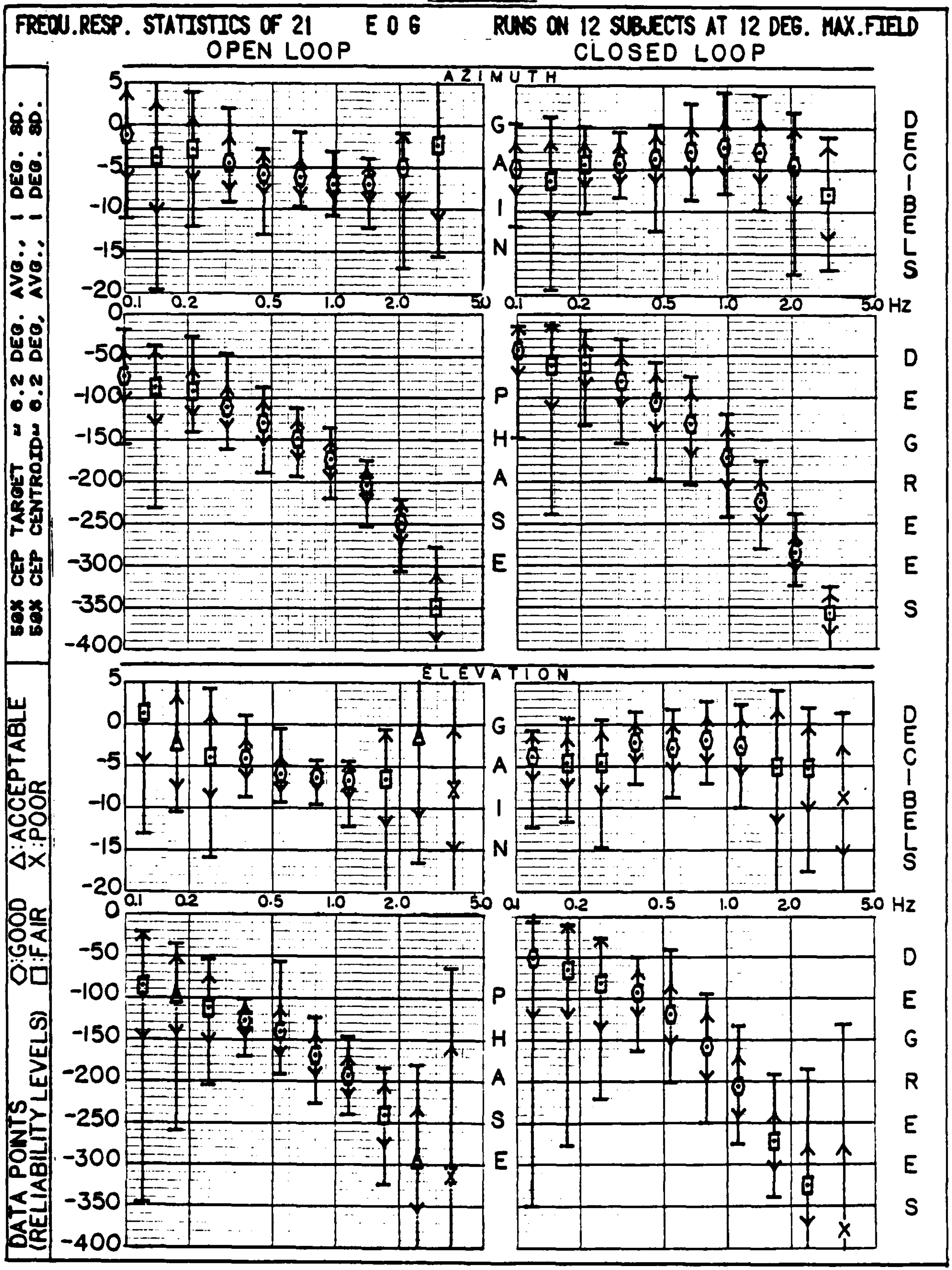

FREQU.RESP. STATISTICS OF 21 E O G RUNS ON 12 SUBJECTS AT 12 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 0.2 DEG, AVG., 1 DEG. SD.
50% CEP CENTROID= 0.2 DEG, AVG., 1 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
O:GOOD □:FAIR
Δ:ACCEPTABLE X:POOR

Table B-4 (a)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. W/O FB RUNS AT 6 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 2.1 DEG, STD. DEV.= 0.1 DEG, RANGE: 1.9. . .2.3 DEG
50% CEP CENTROID: AVG.= 2.1 DEG, STD. DEV.= 0.2 DEG, RANGE: 1.9. . .2.3 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-1.6	-12.4	0.9	7.5	GOOD	-3.0	-2.5	-0.8	-0.5	GOOD	-25.0	-20.0	-4.9	-2.7
0.143	-1.8	-22.2	0.3	7.7	GOOD	-2.3	-2.1	-1.4	-1.4	GOOD	-35.9	-29.9	-14.6	-14.8
0.209	-2.8	-25.8	1.7	9.5	GOOD	-4.9	-4.5	-1.1	-0.3	GOOD	-40.7	-35.3	-16.3	-14.5
0.308	-2.3	-40.8	1.4	4.4	GOOD	-4.9	-3.7	-0.8	-0.6	GOOD	-46.5	-45.2	-36.4	-34.9
0.450	-2.0	-50.1	0.6	4.7	GOOD	-3.0	-2.6	-1.3	-1.2	GOOD	-58.8	-54.8	-45.4	-45.0
0.659	-2.9	-72.1	0.7	8.9	GOOD	-3.7	-3.7	-2.2	-1.8	GOOD	-87.4	-81.0	-63.3	-56.9
0.967	-3.9	-97.4	1.5	7.5	GOOD	-6.6	-5.4	-2.4	-1.9	GOOD	-109.1	-104.9	-90.0	-84.1
1.406	-4.1	-140.0	1.9	11.5	GOOD	-6.2	-6.0	-2.2	-0.7	GOOD	-159.3	-151.5	-128.5	-121.7
2.055	-5.7	-196.5	2.4	19.8	FAIR	-7.8	-8.1	-3.3	-0.4	FAIR	-216.5	-216.3	-176.7	-163.3
3.000	-9.6	-262.9	3.4	36.5	ACPT	-14.7	-13.0	-6.2	-5.5	ACPT	-305.2	-299.4	-226.5	-201.0

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	9.3	-54.2	2.5	29.1	FAIR	5.7	6.8	11.8	13.3	FAIR	-84.2	-83.3	-25.2	-9.4
0.143	6.5	-72.4	2.2	13.2	POOR	2.6	4.4	8.7	9.0	POOR	-88.1	-85.6	-59.2	-52.0
0.209	4.1	-71.0	4.2	16.6	FAIR	-1.5	-0.1	8.3	10.3	FAIR	-91.6	-87.6	-54.5	-37.9
0.308	1.2	-91.2	1.3	13.3	GOOD	-1.1	-0.1	2.5	3.2	GOOD	-108.3	-104.5	-77.9	-68.4
0.450	0.2	-101.5	0.7	6.3	GOOD	-0.9	-0.5	0.9	0.9	GOOD	-109.1	-107.7	-95.2	-95.0
0.659	-3.2	-112.8	0.9	7.9	GOOD	-5.0	-4.1	-2.3	-2.2	GOOD	-121.5	-120.8	-104.9	-97.3
0.967	-5.9	-127.6	1.0	7.6	GOOD	-7.8	-6.9	-4.9	-4.8	GOOD	-136.7	-135.2	-120.0	-115.5
1.406	-7.8	-155.0	1.1	8.4	GOOD	-9.3	-8.9	-6.7	-6.0	GOOD	-167.0	-163.3	-146.6	-140.7
2.055	-9.2	-190.2	1.6	12.6	FAIR	-10.8	-10.8	-7.6	-5.8	FAIR	-204.9	-202.8	-177.5	-168.5
3.000	-10.1	-246.6	3.6	30.3	ACPT	-14.4	-13.7	-6.5	-3.7	ACPT	-276.7	-277.0	-216.3	-194.3

Table B-4 (b)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. W/O FB RUNS AT 6 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 2.1 DEG, STD. DEV.= 0.1 DEG, RANGE: 1.9. . .2.3 DEG
50% CEP CENTROID: AVG.= 2.1 DEG, STD. DEV.= 0.2 DEG, RANGE: 1.9. . .2.3 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-0.6	-5.0	1.2	16.1	GOOD	-2.1	-1.8	0.7	1.0	GOOD	-20.0	-21.0	11.1	25.7
0.176	-0.3	-31.1	2.0	14.0	GOOD	-3.9	-2.3	1.6	1.8	GOOD	-58.0	-45.1	-17.1	-14.8
0.253	-2.3	-28.8	2.8	28.9	FAIR	-7.8	-5.1	0.5	0.8	FAIR	-76.9	-57.6	0.1	14.0
0.374	-2.4	-48.1	2.0	10.8	GOOD	-5.1	-4.4	-0.4	0.5	GOOD	-63.3	-58.9	-37.3	-33.3
0.549	-2.0	-63.8	2.1	14.7	GOOD	-6.1	-4.2	0.1	0.7	GOOD	-91.1	-78.6	-49.1	-41.9
0.802	-2.7	-85.6	1.7	14.1	GOOD	-5.5	-4.3	-1.0	-0.4	GOOD	-104.5	-99.7	-71.6	-58.5
1.165	-1.9	-132.1	1.9	19.8	GOOD	-4.5	-3.7	-0.0	1.2	GOOD	-172.1	-151.8	-112.3	-113.7
1.703	-5.0	-171.5	4.9	10.0	FAIR	-15.1	-9.9	-0.1	0.2	FAIR	-186.4	-181.6	-161.5	-156.0
2.483	-5.6	-233.9	3.8	38.2	ACPT	-11.9	-9.4	-1.8	0.6	ACPT	-268.7	-272.1	-195.7	-153.7
3.626	-9.7	-333.4	7.9	65.1	POOR	-19.8	-17.6	-1.8	2.5	POOR	-437.5	-398.5	-268.2	-226.8

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	10.5	-106.6	3.9	80.3	POOR	6.9	6.5	14.4	18.6	POOR	-245.4	-186.9	-26.3	9.7
0.176	5.1	-97.8	3.3	28.3	ACPT	0.4	1.9	8.4	9.5	ACPT	-125.7	-126.1	-69.4	-57.7
0.253	2.9	-69.5	5.3	51.5	FAIR	-3.5	-2.4	8.2	11.9	FAIR	-132.0	-121.1	-18.0	23.4
0.374	-0.1	-96.4	2.0	17.9	GOOD	-3.8	-2.0	1.9	2.4	GOOD	-124.2	-114.3	-78.6	-63.0
0.549	-1.6	-112.0	2.6	12.1	FAIR	-7.1	-4.2	1.0	0.9	FAIR	-125.8	-124.1	-100.0	-89.8
0.802	-4.2	-122.6	1.0	14.9	GOOD	-5.8	-5.3	-3.2	-2.9	GOOD	-134.2	-137.6	-107.7	-90.4
1.165	-6.2	-152.7	0.9	12.4	GOOD	-7.6	-7.1	-5.3	-4.9	GOOD	-175.8	-165.2	-140.3	-139.1
1.703	-9.1	-175.1	3.5	5.5	FAIR	-16.5	-12.6	-5.6	-5.7	FAIR	-183.9	-180.6	-169.7	-168.1
2.483	-8.0	-212.9	3.3	25.1	ACPT	-13.7	-11.3	-4.7	-3.3	ACPT	-234.9	-238.0	-187.7	-159.0
3.626	-9.6	-275.3	7.0	78.8	POOR	-18.9	-16.5	-2.6	-0.9	POOR	-378.1	-354.0	-196.5	-139.0

Table B-5 (a)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. W/O FB RUNS AT 9 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 2.9 DEG, STD. DEV.= 0.2 DEG, RANGE: 2.6. . .3.2 DEG
50% CEP CENTROID: AVG.= 2.8 DEG, STD. DEV.= 0.3 DEG, RANGE: 2.5. . .3.2 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-1.8	-10.9	1.7	4.3	GOOD	-5.3	-3.5	-0.1	-0.4	GOOD	-18.8	-15.2	-6.6	-5.1
0.143	-1.9	-13.8	2.1	4.9	GOOD	-6.3	-3.9	0.2	-0.4	GOOD	-17.7	-18.8	-8.9	-3.3
0.209	-1.6	-22.0	1.8	4.8	GOOD	-5.4	-3.4	0.1	-0.5	GOOD	-29.4	-26.8	-17.2	-16.2
0.308	-1.5	-36.2	0.7	11.0	GOOD	-3.0	-2.2	-0.8	-0.9	GOOD	-57.9	-47.2	-25.2	-21.5
0.450	-2.1	-42.7	1.1	5.6	GOOD	-4.4	-3.2	-1.1	-1.2	GOOD	-50.2	-48.3	-37.1	-32.8
0.659	-2.1	-63.5	0.9	5.6	GOOD	-3.5	-3.0	-1.2	-0.8	GOOD	-71.8	-69.1	-57.9	-57.2
0.967	-3.1	-92.7	2.5	5.6	GOOD	-8.0	-5.6	-0.6	0.3	GOOD	-104.1	-98.3	-87.1	-87.6
1.406	-4.1	-138.9	1.8	9.1	GOOD	-6.5	-5.9	-2.4	-0.9	GOOD	-150.4	-148.0	-129.8	-126.6
2.055	-5.2	-186.4	2.5	21.9	FAIR	-7.9	-7.7	-2.8	-0.4	FAIR	-218.9	-208.3	-164.6	-150.3
3.000	-7.4	-253.3	4.7	20.5	FAIR	-16.6	-12.2	-2.7	-2.0	FAIR	-276.7	-273.9	-232.8	-218.7

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	9.6	-55.6	3.9	27.7	FAIR	1.5	5.7	13.5	13.0	FAIR	-91.7	-83.2	-27.9	-11.1
0.143	8.9	-62.1	4.8	27.2	FAIR	-1.2	4.1	13.7	12.9	FAIR	-87.8	-89.3	-34.9	-18.1
0.209	6.2	-79.3	3.2	21.1	GOOD	0.4	3.0	9.4	10.2	GOOD	-95.3	-100.4	-58.2	-33.2
0.308	3.4	-93.4	2.6	8.6	GOOD	-1.7	0.8	6.0	7.1	GOOD	-101.9	-102.0	-84.8	-77.4
0.450	1.1	-93.7	0.8	12.8	GOOD	0.1	0.2	1.9	2.6	GOOD	-104.2	-106.5	-80.9	-66.1
0.659	-1.7	-111.1	1.1	4.3	GOOD	-3.1	-2.8	-0.6	-0.1	GOOD	-114.1	-115.4	-106.8	-102.9
0.967	-5.1	-127.3	1.9	7.3	GOOD	-8.7	-7.0	-3.3	-2.8	GOOD	-135.2	-134.6	-120.0	-112.8
1.406	-7.8	-154.7	1.2	5.2	GOOD	-9.6	-9.0	-6.6	-5.9	GOOD	-159.8	-159.9	-149.5	-146.7
2.055	-9.0	-184.4	1.5	14.8	FAIR	-10.7	-10.5	-7.5	-6.1	FAIR	-207.6	-199.2	-169.6	-160.6
3.000	-9.1	-232.6	4.1	16.4	FAIR	-17.2	-13.2	-5.0	-3.6	FAIR	-251.4	-249.1	-216.2	-203.8

Table B-5 (b)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. W/O FB RUNS AT 9 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 2.9 DEG, STD. DEV.= 0.2 DEG, RANGE: 2.6. . .3.2 DEG
50% CEP CENTROID: AVG.= 2.8 DEG, STD. DEV.= 0.3 DEG, RANGE: 2.5. . .3.2 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-0.6	-16.6	0.9	5.2	GOOD	-2.3	-1.5	0.3	0.4	GOOD	-25.5	-21.8	-11.3	-8.4
0.176	-1.9	-24.6	2.6	13.8	GOOD	-7.5	-4.5	0.7	0.1	GOOD	-53.5	-38.4	-10.8	-10.6
0.253	-1.0	-26.7	1.2	5.5	GOOD	-2.7	-2.1	0.2	0.5	GOOD	-32.5	-32.1	-21.2	-16.9
0.374	-1.5	-41.6	1.5	4.5	GOOD	-4.6	-3.0	-0.1	-0.3	GOOD	-49.2	-46.1	-37.1	-35.8
0.549	-1.4	-53.5	1.2	9.9	GOOD	-3.4	-2.6	-0.3	-0.2	GOOD	-72.4	-63.4	-43.7	-44.9
0.802	-1.6	-82.1	1.3	5.9	GOOD	-4.0	-2.9	-0.2	0.1	GOOD	-90.8	-88.0	-76.2	-75.0
1.165	-1.8	-114.9	0.9	9.4	GOOD	-2.9	-2.7	-1.0	-0.1	GOOD	-131.5	-124.3	-105.6	-105.3
1.703	-3.6	-161.4	2.2	6.1	GOOD	-6.6	-5.7	-1.4	-0.5	GOOD	-168.6	-167.5	-155.3	-153.4
2.483	-5.6	-215.4	2.8	21.8	FAIR	-8.3	-8.4	-2.9	-1.0	FAIR	-241.7	-237.2	-193.5	-176.1
3.626	-8.1	-324.5	3.0	36.0	ACPT	-12.8	-11.0	-5.1	-3.6	ACPT	-357.5	-360.5	-288.5	-253.0

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	10.6	-87.8	3.5	11.5	FAIR	4.6	7.0	14.1	16.4	FAIR	-107.4	-99.3	-76.3	-72.4
0.176	6.2	-80.1	5.5	19.9	GOOD	-5.8	0.7	11.6	10.5	GOOD	-103.2	-100.0	-60.2	-41.6
0.253	6.0	-91.8	2.6	12.0	GOOD	2.7	3.4	8.6	9.9	GOOD	-109.0	-103.8	-79.8	-76.4
0.374	1.9	-98.9	1.9	8.2	GOOD	-2.2	-0.1	3.8	3.6	GOOD	-109.2	-107.0	-90.7	-85.0
0.549	0.1	-107.7	1.8	7.6	GOOD	-3.6	-1.7	1.9	2.1	GOOD	-118.9	-115.3	-100.2	-93.9
0.802	-3.2	-125.6	1.3	2.4	GOOD	-5.5	-4.5	-2.0	-1.9	GOOD	-129.1	-128.0	-123.2	-122.6
1.165	-5.5	-143.7	0.7	5.4	GOOD	-6.4	-6.2	-4.8	-4.2	GOOD	-152.4	-149.0	-138.3	-135.5
1.703	-7.9	-168.7	1.3	4.1	GOOD	-9.8	-9.3	-6.6	-6.2	GOOD	-173.6	-172.9	-164.6	-162.4
2.483	-8.9	-202.8	2.0	14.7	FAIR	-11.1	-10.8	-6.9	-5.4	FAIR	-225.7	-217.5	-188.0	-177.2
3.626	-5.8	-309.5	3.3	46.2	ACPT	-10.6	-9.1	-2.5	-1.1	ACPT	-355.9	-355.7	-263.3	-230.1

Table B-6 (a)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. W/O FB RUNS AT 12 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 3.8 DEG, STD. DEV.= 0.2 DEG, RANGE: 3.6. . .4.1 DEG
50% CEP CENTROID: AVG.= 3.8 DEG, STD. DEV.= 0.2 DEG, RANGE: 3.6. . .4.1 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-1.2	-11.2	0.3	1.3	GOOD	-1.6	-1.5	-0.9	-0.8	GOOD	-13.0	-12.5	-9.9	-9.5
0.143	-1.5	-16.6	1.0	4.1	GOOD	-3.1	-2.5	-0.6	-0.4	GOOD	-21.4	-20.7	-12.5	-9.2
0.209	-1.4	-20.5	0.5	4.2	GOOD	-2.2	-2.0	-0.9	-0.8	GOOD	-28.1	-24.7	-16.3	-15.7
0.308	-1.7	-33.8	1.0	2.8	GOOD	-3.6	-2.6	-0.7	-0.8	GOOD	-37.3	-36.6	-31.1	-29.1
0.450	-1.9	-44.7	0.6	4.8	GOOD	-3.0	-2.5	-1.3	-1.1	GOOD	-53.6	-49.5	-39.9	-39.7
0.659	-1.9	-61.9	0.5	3.9	GOOD	-2.8	-2.5	-1.4	-1.3	GOOD	-70.1	-65.8	-58.1	-57.6
0.967	-2.2	-93.2	0.5	8.5	GOOD	-3.2	-2.7	-1.6	-1.6	GOOD	-108.8	-101.7	-84.7	-85.1
1.406	-3.3	-131.8	1.1	11.8	GOOD	-5.1	-4.4	-2.2	-1.8	GOOD	-145.1	-143.7	-120.0	-118.3
2.055	-5.2	-184.7	1.4	17.8	GOOD	-7.8	-6.7	-3.8	-3.7	GOOD	-210.6	-202.5	-166.9	-155.0
3.000	-6.3	-259.8	1.5	26.0	FAIR	-9.1	-7.8	-4.9	-5.0	FAIR	-297.2	-285.8	-233.8	-219.7

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	11.8	-61.0	1.3	7.7	GOOD	10.5	10.5	13.1	14.0	GOOD	-74.2	-68.7	-53.3	-52.3
0.143	8.5	-67.7	2.6	17.3	FAIR	4.6	6.0	11.1	13.1	FAIR	-93.8	-85.1	-50.4	-46.0
0.209	7.3	-75.0	1.3	12.4	GOOD	5.4	6.0	8.6	8.9	GOOD	-88.8	-87.4	-62.6	-56.2
0.308	3.4	-89.9	1.3	8.1	GOOD	0.7	2.0	4.7	5.1	GOOD	-100.8	-98.1	-81.8	-76.1
0.450	1.1	-97.2	0.8	7.0	GOOD	-0.4	0.3	1.8	1.8	GOOD	-104.1	-104.3	-90.2	-84.5
0.659	-1.4	-110.5	0.7	2.8	GOOD	-2.6	-2.2	-0.7	-0.4	GOOD	-114.1	-113.3	-107.7	-105.6
0.967	-4.4	-130.0	0.8	4.4	GOOD	-6.0	-5.2	-3.6	-3.7	GOOD	-137.0	-134.4	-125.7	-124.7
1.406	-7.0	-151.1	0.8	7.6	GOOD	-8.6	-7.8	-6.2	-6.2	GOOD	-159.7	-158.7	-143.5	-141.2
2.055	-9.0	-183.1	0.9	11.6	GOOD	-10.7	-9.9	-8.0	-7.9	GOOD	-200.6	-194.8	-171.5	-163.8
3.000	-7.7	-237.8	1.0	22.9	FAIR	-9.2	-8.7	-6.6	-6.2	FAIR	-276.7	-260.8	-214.9	-205.6

Table B-6 (b)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. W/O FB RUNS AT 12 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 3.8 DEG, STD. DEV.= 0.2 DEG, RANGE: 3.6. . .4.1 DEG
50% CEP CENTROID: AVG.= 3.8 DEG, STD. DEV.= 0.2 DEG, RANGE: 3.6. . .4.1 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-0.9	-13.0	0.9	5.6	GOOD	-2.2	-1.8	0.0	0.7	GOOD	-18.9	-18.6	-7.4	-1.1
0.176	-1.2	-20.3	0.9	4.7	GOOD	-3.1	-2.1	-0.3	-0.2	GOOD	-29.0	-25.0	-15.5	-13.7
0.253	-0.9	-28.8	0.8	4.0	GOOD	-2.0	-1.7	-0.1	0.4	GOOD	-33.7	-32.8	-24.9	-22.1
0.374	-1.3	-36.8	1.2	2.7	GOOD	-3.1	-2.5	-0.2	0.4	GOOD	-40.2	-39.5	-34.1	-32.6
0.549	-1.1	-52.0	0.8	3.1	GOOD	-2.1	-1.9	-0.3	-0.2	GOOD	-56.5	-55.1	-49.0	-48.5
0.802	-1.1	-75.6	0.8	4.3	GOOD	-2.5	-1.9	-0.3	0.0	GOOD	-82.1	-79.9	-71.3	-68.7
1.165	-1.7	-109.4	1.4	5.7	GOOD	-4.4	-3.1	-0.3	-0.1	GOOD	-117.8	-115.1	-103.7	-103.1
1.703	-2.9	-158.4	1.6	11.4	GOOD	-5.6	-4.5	-1.3	-0.8	GOOD	-172.0	-169.8	-147.0	-139.9
2.483	-4.5	-223.1	2.0	20.9	GOOD	-8.4	-6.5	-2.6	-2.6	GOOD	-245.5	-244.1	-202.2	-188.5
3.626	-7.8	-309.7	2.9	21.1	ACPT	-12.0	-10.7	-4.8	-3.2	ACPT	-342.3	-330.8	-288.7	-282.7

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	10.5	-70.8	1.3	33.4	GOOD	8.7	9.2	11.8	12.1	GOOD	-113.8	-104.2	-37.5	-5.0
0.176	7.9	-81.2	2.9	11.1	GOOD	3.9	5.1	10.8	12.3	GOOD	-91.6	-92.2	-70.1	-59.0
0.253	5.4	-94.2	1.6	9.3	GOOD	3.7	3.9	7.0	8.3	GOOD	-109.3	-103.5	-85.0	-81.1
0.374	2.9	-95.5	1.1	11.1	GOOD	1.6	1.8	4.0	4.8	GOOD	-113.4	-106.7	-84.4	-77.3
0.549	0.4	-108.6	0.7	5.6	GOOD	-0.7	-0.3	1.2	1.6	GOOD	-115.6	-114.2	-103.0	-101.2
0.802	-2.4	-123.0	0.6	4.0	GOOD	-3.4	-3.0	-1.8	-1.4	GOOD	-130.9	-127.0	-119.0	-118.4
1.165	-5.2	-140.6	0.7	5.8	GOOD	-6.6	-5.9	-4.5	-4.4	GOOD	-148.7	-146.4	-134.8	-130.4
1.703	-7.5	-167.1	0.9	7.6	GOOD	-8.8	-8.3	-6.6	-6.4	GOOD	-175.6	-174.7	-159.5	-153.4
2.483	-7.9	-206.9	1.6	13.1	GOOD	-11.2	-9.5	-6.3	-6.4	GOOD	-222.4	-220.0	-193.8	-186.2
3.626	-6.1	-287.6	3.0	29.3	ACPT	-11.5	-9.1	-3.2	-2.0	ACPT	-331.9	-316.9	-258.3	-250.1

Figure B-4

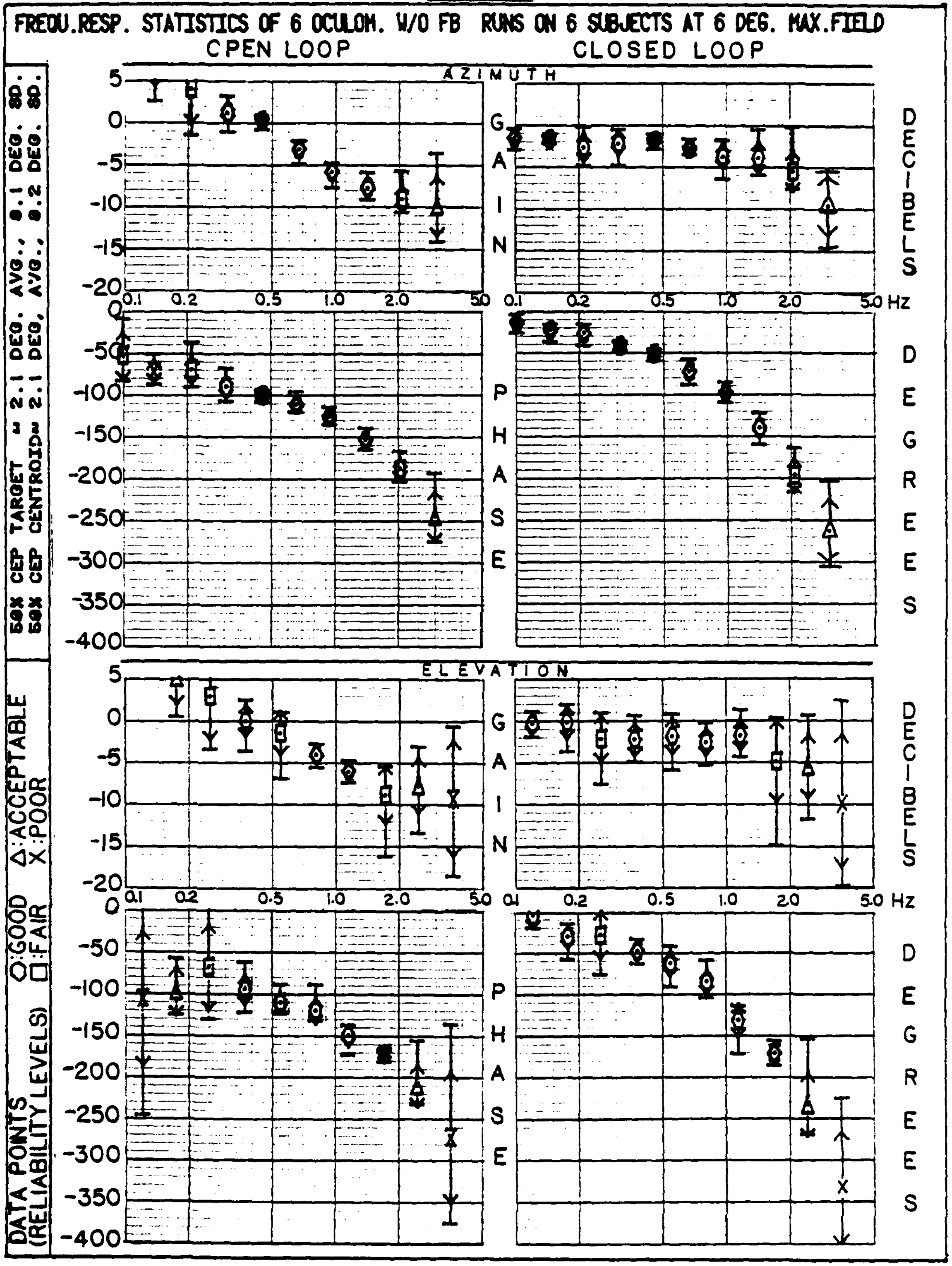

FREQU.RESP. STATISTICS OF 6 OCULOM. W/O FB RUNS ON 6 SUBJECTS AT 6 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 2.1 DEG. AVG., 0.1 DEG. SD.
50% CEP CENTROID= 2.1 DEG. AVG., 0.2 DEG. SD.
DATA POINTS (RELIABILITY LEVELS) ○:GOOD □:FAIR △:ACCEPTABLE X:POOR

Figure B-5

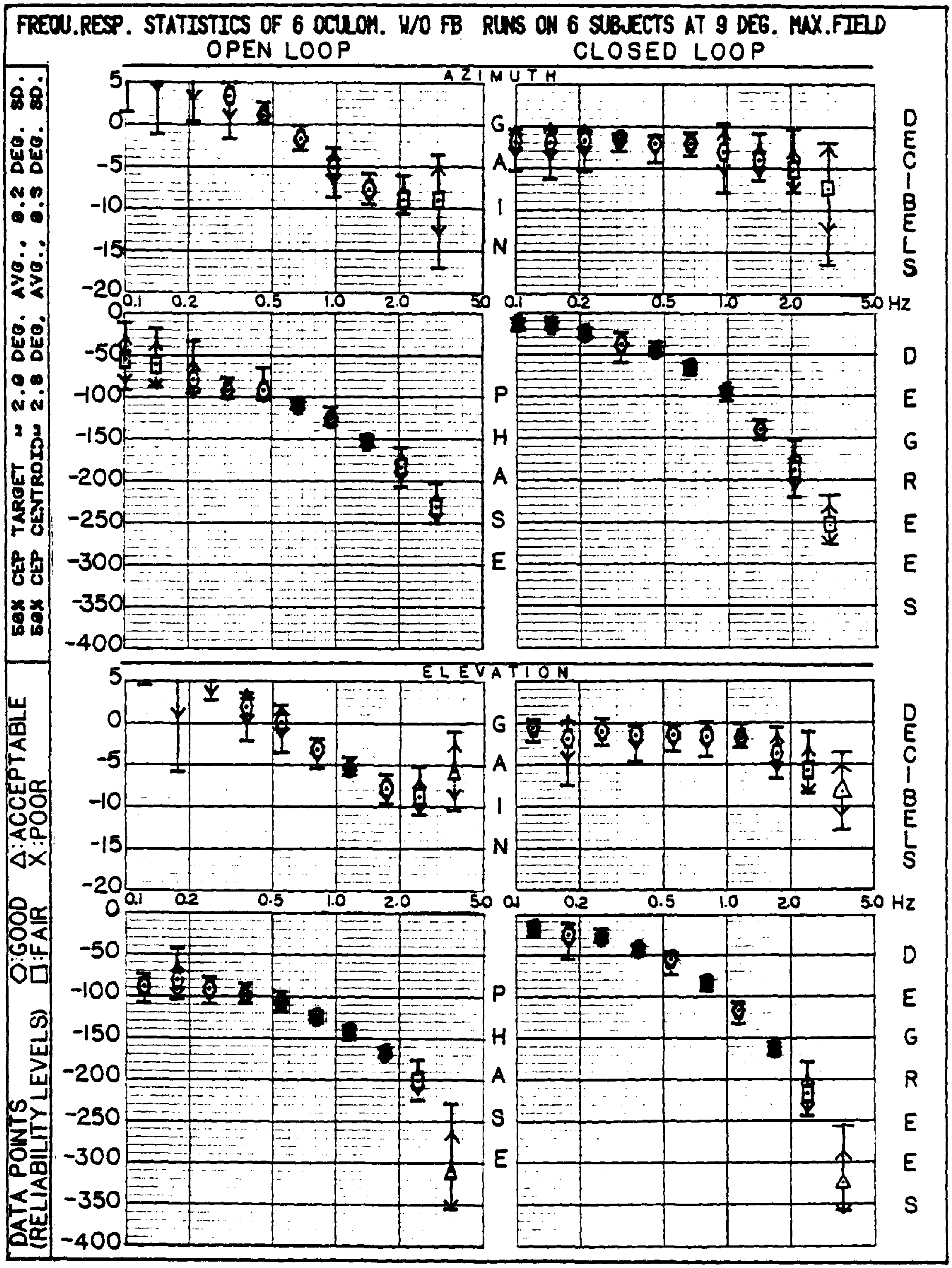

FREQU.RESP. STATISTICS OF 6 OCULOM. W/O FB RUNS ON 6 SUBJECTS AT 9 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
50% CEP TARGET = 2.0 DEG. AVG., 0.2 DEG. SD.
50% CEP CENTROID= 2.8 DEG. AVG., 0.3 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
○:GOOD □:FAIR
△:ACCEPTABLE X:POOR
GAIN
PHASE
DECIBELS
DEGREES
Hz
0.1 0.2 0.5 1.0 2.0 5.0
5 0 -5 -10 -15 -20
0 -50 -100 -150 -200 -250 -300 -350 -400

Figure B-6

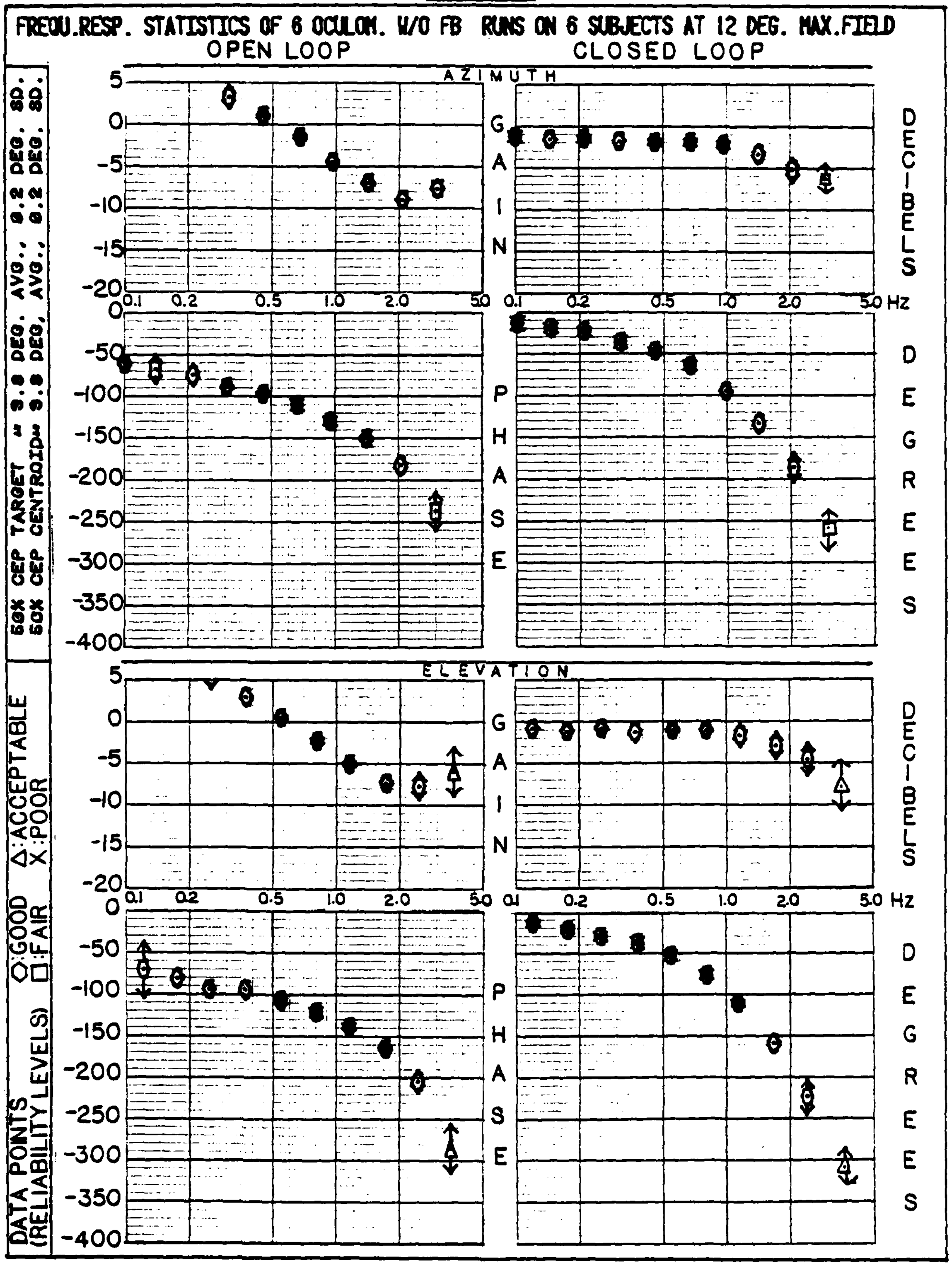

FREQU.RESP. STATISTICS OF 6 OCULOM. W/O FB RUNS ON 6 SUBJECTS AT 12 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 9.8 DEG. AVG., 8.2 DEG. SD.
50% CEP CENTROID= 9.8 DEG. AVG., 8.2 DEG. SD.
DATA POINTS (RELIABILITY LEVELS) ○:GOOD □:FAIR △:ACCEPTABLE X:POOR

Table B-7 (a)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. WITH FB RUNS AT 6 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 2.1 DEG, STD. DEV.= 0.2 DEG, RANGE: 1.8. . .2.5 DEG
50% CEP CENTROID: AVG.= 2.0 DEG, STD. DEV.= 0.2 DEG, RANGE: 1.8. . .2.2 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-0.9	-12.8	0.9	5.3	GOOD	-2.3	-1.8	-0.1	0.4	GOOD	-20.1	-18.2	-7.5	-2.7
0.143	-1.5	-22.9	0.8	7.1	GOOD	-3.0	-2.3	-0.7	-0.7	GOOD	-36.9	-30.0	-15.9	-13.2
0.209	-1.4	-29.2	1.6	7.5	GOOD	-4.4	-3.0	0.2	0.6	GOOD	-40.0	-36.7	-21.7	-18.4
0.308	-2.2	-36.7	1.2	7.2	GOOD	-4.2	-3.4	-0.9	-0.7	GOOD	-47.4	-43.9	-29.5	-27.7
0.450	-2.3	-56.4	0.6	11.8	GOOD	-2.9	-2.8	-1.7	-1.5	GOOD	-78.2	-68.2	-44.6	-40.3
0.659	-2.8	-74.3	1.7	12.9	GOOD	-6.3	-4.5	-1.1	-0.9	GOOD	-98.7	-87.2	-61.3	-61.5
0.967	-3.6	-105.1	1.4	14.1	GOOD	-5.9	-5.0	-2.2	-2.2	GOOD	-128.8	-119.2	-91.1	-85.5
1.406	-6.1	-147.2	3.5	22.5	FAIR	-13.6	-9.7	-2.6	-3.6	FAIR	-189.2	-169.7	-124.7	-113.9
2.055	-7.8	-185.0	1.8	22.4	ACPT	-10.0	-9.7	-6.0	-4.2	ACPT	-213.8	-207.4	-162.5	-154.0
3.000	-9.9	-240.1	4.8	33.7	POOR	-17.5	-14.7	-5.2	-2.9	POOR	-292.7	-273.8	-206.5	-208.3

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	10.9	-72.1	2.1	30.1	ACPT	8.2	8.7	13.0	14.5	ACPT	-108.4	-102.3	-42.0	-11.5
0.143	6.6	-77.7	2.4	14.2	FAIR	3.5	4.3	9.0	10.7	FAIR	-100.7	-91.9	-63.6	-58.7
0.209	4.8	-88.2	2.8	15.7	GOOD	-0.8	2.1	7.6	7.6	GOOD	-114.4	-104.0	-72.5	-67.8
0.308	2.2	-87.5	1.4	15.5	GOOD	-0.3	0.8	3.6	4.0	GOOD	-104.8	-103.0	-71.9	-60.1
0.450	-0.8	-104.2	1.6	9.6	GOOD	-3.7	-2.4	0.7	0.8	GOOD	-117.8	-113.8	-94.6	-85.7
0.659	-3.3	-115.2	1.7	11.3	GOOD	-5.7	-5.0	-1.6	-1.2	GOOD	-131.3	-126.5	-104.0	-97.4
0.967	-6.0	-133.9	1.4	9.0	GOOD	-8.6	-7.4	-4.7	-4.7	GOOD	-145.5	-142.9	-124.9	-121.1
1.406	-9.2	-159.4	2.8	14.9	FAIR	-15.2	-12.0	-6.5	-6.8	FAIR	-187.6	-174.3	-144.5	-138.7
2.055	-10.7	-183.9	1.3	15.9	ACPT	-12.3	-12.0	-9.4	-8.2	ACPT	-205.0	-199.8	-168.0	-161.8
3.000	-11.5	-228.3	3.8	30.8	POOR	-18.4	-15.3	-7.7	-7.1	POOR	-271.9	-259.1	-197.5	-199.6

Table B-7 (b)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. WITH FB RUNS AT 6 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 2.1 DEG, STD. DEV.= 0.2 DEG, RANGE: 1.8. . .2.5 DEG
50% CEP CENTROID: AVG.= 2.0 DEG, STD. DEV.= 0.2 DEG, RANGE: 1.8. . .2.2 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-0.7	-20.0	1.4	6.2	GOOD	-2.7	-2.0	0.7	1.7	GOOD	-28.7	-26.2	-13.8	-10.0
0.176	-1.6	-22.9	1.8	10.7	GOOD	-5.0	-3.4	0.1	-0.2	GOOD	-34.6	-33.7	-12.2	-4.5
0.253	-1.8	-31.8	1.0	9.0	GOOD	-3.3	-2.8	-0.8	0.1	GOOD	-50.9	-40.8	-22.8	-23.3
0.374	-2.9	-39.7	1.6	3.6	GOOD	-5.5	-4.5	-1.3	-0.8	GOOD	-45.1	-43.3	-36.1	-35.9
0.549	-2.7	-66.2	1.7	11.5	GOOD	-6.2	-4.4	-1.0	-1.3	GOOD	-83.6	-77.8	-54.7	-52.9
0.802	-3.3	-90.2	2.3	12.8	GOOD	-7.1	-5.6	-1.1	-1.0	GOOD	-115.1	-103.0	-77.4	-73.6
1.165	-4.0	-132.4	1.6	19.4	GOOD	-5.8	-5.6	-2.4	-2.0	GOOD	-159.2	-151.7	-113.0	-103.5
1.703	-7.2	-179.2	2.7	21.6	ACPT	-10.8	-9.9	-4.5	-3.3	ACPT	-207.8	-200.8	-157.7	-147.2
2.483	-9.8	-191.7	6.5	70.1	ACPT	-23.7	-16.3	-3.4	-4.8	ACPT	-264.6	-261.8	-121.6	-87.4
3.626	-12.8	-276.7	6.4	150.7	POOR	-24.0	-19.3	-6.4	-5.7	POOR	-391.3	-427.4	-126.0	52.5

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	7.9	-85.7	2.0	27.6	GOOD	4.7	5.9	9.9	11.4	GOOD	-127.0	-113.4	-58.1	-34.2
0.176	7.6	-79.0	6.7	19.0	FAIR	-0.2	0.8	14.3	19.5	FAIR	-100.7	-98.0	-59.9	-52.8
0.253	3.8	-85.8	2.0	15.2	GOOD	0.0	1.8	5.8	6.1	GOOD	-105.4	-101.0	-70.6	-58.9
0.374	0.7	-86.1	1.6	13.8	GOOD	-1.7	-0.8	2.3	3.5	GOOD	-102.3	-99.9	-72.3	-64.8
0.549	-2.4	-110.7	2.3	5.5	GOOD	-6.7	-4.7	-0.0	0.0	GOOD	-121.7	-116.2	-105.3	-105.2
0.802	-5.0	-125.3	2.2	7.4	GOOD	-8.0	-7.1	-2.8	-3.1	GOOD	-136.1	-132.7	-117.9	-115.8
1.165	-7.4	-150.6	1.3	12.4	GOOD	-9.1	-8.7	-6.1	-5.4	GOOD	-166.4	-163.1	-138.2	-128.6
1.703	-10.3	-180.8	1.9	15.0	ACPT	-12.8	-12.2	-8.4	-7.7	ACPT	-201.7	-195.8	-165.8	-159.6
2.483	-11.4	-185.1	5.7	57.2	ACPT	-23.9	-17.1	-5.7	-6.7	ACPT	-248.2	-242.2	-127.9	-106.3
3.626	-10.9	-268.5	7.7	154.2	POOR	-23.4	-18.6	-3.2	0.6	POOR	-396.3	-422.7	-114.3	62.2

Table B-8 (a)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. WITH FB RUNS AT 9 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 3.1 DEG, STD. DEV.= 0.3 DEG, RANGE: 2.7. . .3.6 DEG
50% CEP CENTROID: AVG.= 3.0 DEG, STD. DEV.= 0.3 DEG, RANGE: 2.7. . .3.5 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-1.6	-10.4	1.8	4.6	GOOD	-4.4	-3.4	0.2	0.7	GOOD	-15.9	-15.0	-5.7	-1.4
0.143	-2.2	-15.3	1.6	4.2	GOOD	-5.6	-3.8	-0.6	-0.6	GOOD	-22.2	-19.5	-11.2	-9.1
0.209	-2.2	-28.9	0.5	6.9	GOOD	-2.9	-2.6	-1.7	-1.6	GOOD	-42.3	-35.8	-22.0	-20.7
0.308	-1.7	-34.4	1.3	4.1	GOOD	-3.7	-3.0	-0.4	0.5	GOOD	-39.6	-38.5	-30.3	-28.3
0.450	-2.2	-52.8	0.8	8.0	GOOD	-3.8	-3.0	-1.3	-1.2	GOOD	-61.7	-60.8	-44.7	-42.2
0.659	-2.6	-71.4	0.7	10.8	GOOD	-3.7	-3.3	-1.8	-1.7	GOOD	-88.2	-82.2	-60.6	-58.2
0.967	-3.6	-99.5	1.4	12.0	GOOD	-6.5	-5.0	-2.2	-1.9	GOOD	-118.6	-111.5	-87.6	-81.3
1.406	-5.5	-136.7	1.9	18.9	GOOD	-8.5	-7.4	-3.6	-2.9	GOOD	-168.9	-155.6	-117.8	-116.1
2.055	-9.7	-194.8	3.7	23.1	ACPT	-15.5	-13.4	-6.0	-5.3	ACPT	-221.1	-218.0	-171.7	-157.0
3.000	-9.4	-254.2	2.3	28.9	FAIR	-13.3	-11.7	-7.1	-6.1	FAIR	-294.3	-283.1	-225.4	-211.3

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	10.1	-63.1	4.6	35.1	GOOD	3.5	5.6	14.7	16.1	GOOD	-115.9	-98.2	-28.1	-3.4
0.143	8.0	-59.0	4.0	14.6	FAIR	-0.4	4.0	12.1	11.2	FAIR	-81.4	-73.6	-44.5	-39.6
0.209	4.2	-78.5	2.0	6.1	GOOD	0.9	2.1	6.2	7.0	GOOD	-90.1	-84.6	-72.3	-72.9
0.308	3.0	-89.7	1.3	13.9	GOOD	0.8	1.7	4.4	4.7	GOOD	-114.5	-103.6	-75.8	-72.6
0.450	-0.3	-102.6	1.6	5.6	GOOD	-2.8	-1.9	1.3	2.0	GOOD	-112.5	-108.2	-97.0	-95.4
0.659	-2.8	-114.3	1.4	6.3	GOOD	-4.9	-4.2	-1.4	-0.8	GOOD	-122.9	-120.5	-108.0	-106.6
0.967	-5.7	-130.3	1.5	6.2	GOOD	-8.7	-7.3	-4.2	-4.1	GOOD	-137.4	-136.6	-124.1	-118.2
1.406	-8.6	-151.7	1.5	12.5	GOOD	-11.3	-10.1	-7.0	-6.7	GOOD	-171.9	-164.2	-139.2	-134.7
2.055	-12.1	-192.1	2.9	16.8	ACPT	-16.8	-14.9	-9.2	-8.9	ACPT	-209.9	-208.9	-175.3	-165.1
3.000	-10.6	-239.8	1.2	27.3	FAIR	-12.7	-11.7	-9.4	-9.3	FAIR	-282.0	-267.1	-212.5	-201.1

Table B-8 (b)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. WITH FB RUNS AT 9 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 3.1 DEG, STD. DEV.= 0.3 DEG, RANGE: 2.7. . .3.6 DEG
50% CEP CENTROID: AVG.= 3.0 DEG, STD. DEV.= 0.3 DEG, RANGE: 2.7. . .3.5 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-0.9	-13.6	1.1	1.6	GOOD	-1.9	-1.9	0.2	1.2	GOOD	-16.2	-15.2	-12.1	-11.4
0.176	-1.8	-17.8	1.3	3.5	GOOD	-4.0	-3.1	-0.6	-0.2	GOOD	-21.1	-21.3	-14.4	-10.5
0.253	-1.7	-25.4	1.9	6.9	GOOD	-4.2	-3.6	0.2	1.5	GOOD	-39.0	-32.3	-18.5	-17.0
0.374	-2.0	-41.2	1.6	6.8	GOOD	-4.3	-3.6	-0.4	-0.6	GOOD	-54.7	-48.0	-34.5	-34.0
0.549	-2.3	-62.3	1.8	16.1	GOOD	-5.9	-4.1	-0.4	-0.2	GOOD	-96.7	-78.4	-46.2	-48.6
0.802	-2.6	-87.0	2.1	14.1	GOOD	-6.2	-4.7	-0.5	0.4	GOOD	-110.3	-101.2	-72.9	-66.9
1.165	-3.4	-121.2	1.4	13.9	GOOD	-5.9	-4.7	-2.0	-1.5	GOOD	-138.1	-135.1	-107.4	-101.6
1.703	-4.9	-165.8	2.4	17.1	GOOD	-9.0	-7.3	-2.5	-1.1	GOOD	-181.4	-182.9	-148.7	-136.4
2.483	-8.8	-220.7	3.4	20.2	FAIR	-14.8	-12.2	-5.4	-4.8	FAIR	-245.1	-240.9	-200.6	-194.4
3.626	-11.3	-292.2	6.7	45.5	POOR	-23.9	-18.0	-4.6	-4.0	POOR	-338.1	-337.7	-246.7	-198.7

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	10.5	-75.6	1.2	26.0	GOOD	9.0	9.3	11.7	12.6	GOOD	-125.8	-101.6	-49.5	-48.5
0.176	7.1	-68.1	2.0	21.8	FAIR	4.0	5.0	9.1	9.7	FAIR	-94.7	-89.8	-46.3	-27.2
0.253	5.2	-82.4	3.2	22.5	GOOD	-0.2	1.9	8.4	9.6	GOOD	-124.0	-104.9	-59.9	-47.3
0.374	1.5	-94.2	2.0	12.7	GOOD	-1.0	-0.5	3.5	4.3	GOOD	-113.6	-106.9	-81.5	-76.2
0.549	-1.7	-111.5	2.7	7.2	GOOD	-7.3	-4.3	1.0	1.0	GOOD	-122.0	-118.7	-104.3	-103.1
0.802	-4.2	-125.4	2.2	7.8	GOOD	-8.2	-6.4	-2.1	-1.7	GOOD	-136.3	-133.2	-117.5	-115.0
1.165	-6.7	-144.8	1.3	7.4	GOOD	-8.9	-8.0	-5.4	-4.6	GOOD	-152.4	-152.2	-137.4	-133.0
1.703	-8.7	-171.2	1.6	10.9	GOOD	-11.6	-10.3	-7.2	-6.3	GOOD	-180.9	-182.1	-160.3	-150.7
2.483	-11.1	-210.9	2.5	16.8	FAIR	-15.6	-13.6	-8.6	-8.6	FAIR	-233.2	-227.7	-194.1	-189.5
3.626	-10.2	-274.6	7.3	43.8	POOR	-24.4	-17.4	-2.9	-3.0	POOR	-330.7	-318.4	-230.8	-197.6

Table B-9 (a)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. WITH FB RUNS AT 12 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 4.1 DEG, STD. DEV.= 0.5 DEG, RANGE: 3.5. . .4.8 DEG
50% CEP CENTROID: AVG.= 4.3 DEG, STD. DEV.= 0.5 DEG, RANGE: 3.5. . .4.8 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-1.5	-10.9	1.1	4.3	GOOD	-3.6	-2.6	-0.4	-0.2	GOOD	-18.7	-15.2	-6.5	-5.0
0.143	-2.1	-17.1	1.5	3.7	GOOD	-4.4	-3.6	-0.7	-0.5	GOOD	-22.3	-20.7	-13.4	-12.4
0.209	-2.0	-25.5	0.7	5.1	GOOD	-2.7	-2.7	-1.3	-0.8	GOOD	-34.1	-30.6	-20.5	-18.0
0.308	-1.3	-37.3	0.8	10.1	GOOD	-3.1	-2.2	-0.5	-0.6	GOOD	-52.3	-47.5	-27.2	-27.4
0.450	-1.7	-49.6	0.4	7.2	GOOD	-2.4	-2.2	-1.3	-1.1	GOOD	-63.2	-56.8	-42.4	-41.3
0.659	-2.0	-68.4	1.5	10.6	GOOD	-5.3	-3.5	-0.4	-1.0	GOOD	-88.4	-79.0	-57.8	-56.3
0.967	-2.7	-98.9	1.5	9.8	GOOD	-4.9	-4.2	-1.2	-1.1	GOOD	-112.5	-108.7	-89.1	-85.8
1.406	-4.1	-143.2	2.8	19.0	GOOD	-9.5	-6.8	-1.3	-1.5	GOOD	-177.3	-162.2	-124.2	-120.8
2.055	-8.1	-202.6	3.4	18.9	FAIR	-14.0	-11.5	-4.7	-3.9	FAIR	-231.6	-221.6	-183.7	-174.5
3.000	-9.4	-258.4	3.1	22.3	ACPT	-13.3	-12.5	-6.3	-5.5	ACPT	-280.3	-280.7	-236.1	-226.9

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	10.6	-54.9	2.8	25.1	GOOD	5.3	7.7	13.4	14.0	GOOD	-95.3	-80.0	-29.9	-24.1
0.143	6.8	-63.5	2.8	22.4	FAIR	2.9	4.0	9.6	11.7	FAIR	-90.0	-85.9	-41.1	-29.8
0.209	5.0	-75.9	1.7	10.4	GOOD	2.2	3.4	6.7	7.0	GOOD	-91.4	-86.4	-65.5	-56.2
0.308	3.2	-95.7	2.5	7.5	GOOD	-0.8	0.8	5.7	5.9	GOOD	-112.1	-103.2	-88.2	-89.6
0.450	0.5	-102.7	1.2	5.2	GOOD	-1.4	-0.8	1.7	2.3	GOOD	-112.8	-107.9	-97.5	-97.8
0.659	-2.1	-115.2	1.8	8.4	GOOD	-4.8	-3.9	-0.4	-0.1	GOOD	-126.9	-123.6	-106.8	-100.5
0.967	-5.2	-132.3	1.4	5.3	GOOD	-7.2	-6.5	-3.8	-3.3	GOOD	-138.1	-137.6	-127.0	-125.4
1.406	-7.8	-157.0	1.9	11.9	GOOD	-11.7	-9.7	-6.0	-6.3	GOOD	-178.4	-168.9	-145.1	-145.3
2.055	-10.9	-197.0	2.5	13.7	FAIR	-15.3	-13.4	-8.4	-8.2	FAIR	-214.7	-210.7	-183.3	-176.6
3.000	-10.4	-241.8	2.5	20.9	ACPT	-14.1	-12.9	-7.9	-6.5	ACPT	-265.9	-262.7	-220.9	-213.5

Table B-9 (b)

FREQUENCY RESPONSE STATISTICS FOR 6 OCULOM. WITH FB RUNS AT 12 DEG MAX. FIELD
SUBJECT NO.: 8, 9,12,10,11,13,
NUMBER OF RUNS: 1+ 1+ 1+ 1+ 1+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 6RUNS
50% CEP TARGET : AVG.= 4.1 DEG, STD. DEV.= 0.5 DEG, RANGE: 3.5. . .4.8 DEG
50% CEP CENTROID: AVG.= 4.3 DEG, STD. DEV.= 0.5 DEG, RANGE: 3.5. . .4.8 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-0.9	-40.3	1.5	60.1	GOOD	-3.1	-2.4	0.5	1.1	GOOD	-174.6	-100.4	19.8	-9.8
0.176	-0.2	-41.8	1.9	49.5	GOOD	-2.8	-2.1	1.6	3.1	GOOD	-151.9	-91.4	7.7	-11.2
0.253	-2.9	-35.8	1.9	13.3	FAIR	-6.4	-4.8	-1.1	-0.7	FAIR	-58.3	-49.2	-22.5	-20.5
0.374	-1.1	-46.4	1.6	9.2	GOOD	-3.2	-2.7	0.5	1.0	GOOD	-59.1	-55.6	-37.3	-32.9
0.549	-1.2	-53.3	1.8	11.8	GOOD	-4.4	-3.1	0.6	1.8	GOOD	-72.2	-65.1	-41.5	-38.0
0.802	-2.5	-89.1	1.6	18.2	GOOD	-5.6	-4.2	-0.9	-0.9	GOOD	-117.1	-107.3	-70.8	-68.0
1.165	-2.4	-144.3	2.0	53.1	FAIR	-6.5	-4.4	-0.4	-0.7	FAIR	-259.9	-197.4	-91.2	-96.9
1.703	-3.7	-203.7	4.0	53.4	FAIR	-11.7	-7.6	0.3	1.3	FAIR	-314.6	-257.2	-150.3	-145.2
2.483	-3.8	-203.2	6.3	36.2	ACPT	-13.0	-10.1	2.4	4.3	ACPT	-238.6	-239.4	-167.0	-148.5
3.626	-4.7	-301.9	8.3	47.2	POOR	-16.4	-13.0	3.7	9.5	POOR	-386.9	-349.1	-254.8	-256.8

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	7.2	-96.5	6.6	48.0	FAIR	-7.1	0.5	13.8	11.8	FAIR	-177.0	-144.5	-48.5	-30.9
0.176	5.4	-107.0	5.2	39.5	FAIR	-5.2	0.2	10.6	10.0	FAIR	-166.9	-146.6	-67.5	-65.8
0.253	1.9	-82.0	4.0	16.1	FAIR	-3.9	-2.0	5.9	8.0	FAIR	-98.9	-98.1	-65.8	-52.0
0.374	1.4	-104.5	2.0	12.6	GOOD	-0.9	-0.7	3.4	4.4	GOOD	-122.5	-117.1	-91.9	-92.1
0.549	0.3	-109.8	2.4	10.4	GOOD	-4.3	-2.2	2.7	2.8	GOOD	-127.0	-120.1	-99.4	-96.6
0.802	-4.2	-126.6	2.1	10.5	GOOD	-8.1	-6.3	-2.2	-1.4	GOOD	-140.8	-137.1	-116.1	-109.8
1.165	-5.9	-159.7	1.8	29.4	FAIR	-9.2	-7.7	-4.1	-3.8	FAIR	-224.6	-189.1	-130.3	-136.5
1.703	-6.9	-197.5	3.7	37.4	FAIR	-13.6	-10.6	-3.3	-1.3	FAIR	-276.9	-235.0	-160.1	-160.9
2.483	-8.2	-199.9	3.6	23.4	ACPT	-14.2	-11.8	-4.6	-4.0	ACPT	-225.1	-223.3	-176.5	-167.4
3.626	-6.1	-260.1	6.1	66.8	POOR	-16.3	-12.3	-0.0	3.3	POOR	-398.9	-326.9	-193.3	-188.3

Figure B-7

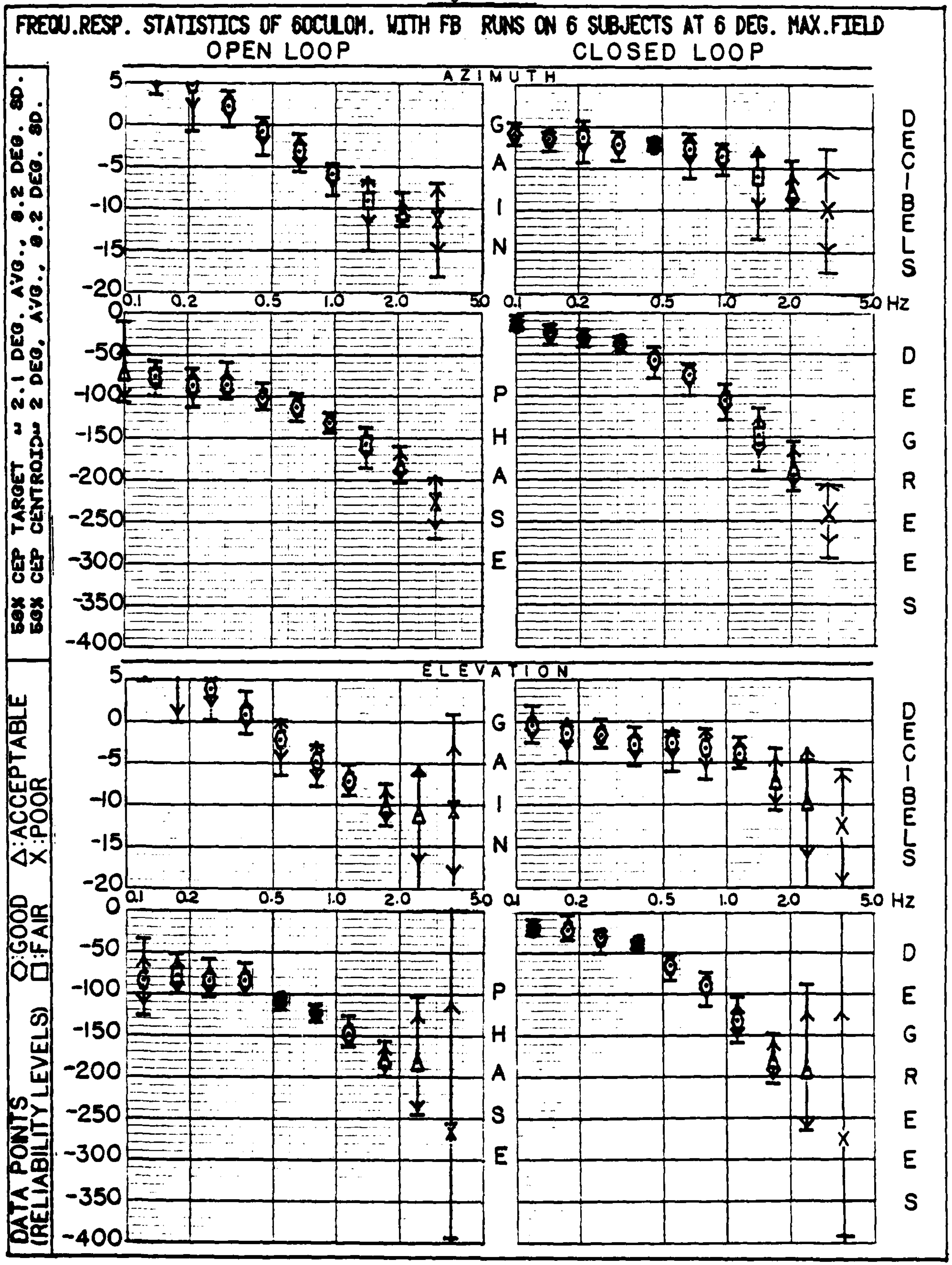

FREQU.RESP. STATISTICS OF 6OCULOM. WITH FB RUNS ON 6 SUBJECTS AT 6 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 2.1 DEG. AVG., 0.2 DEG. SD.
50% CEP CENTROID = 2 DEG. AVG., 0.2 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
○:GOOD □:FAIR
Δ:ACCEPTABLE X:POOR

Figure B-8

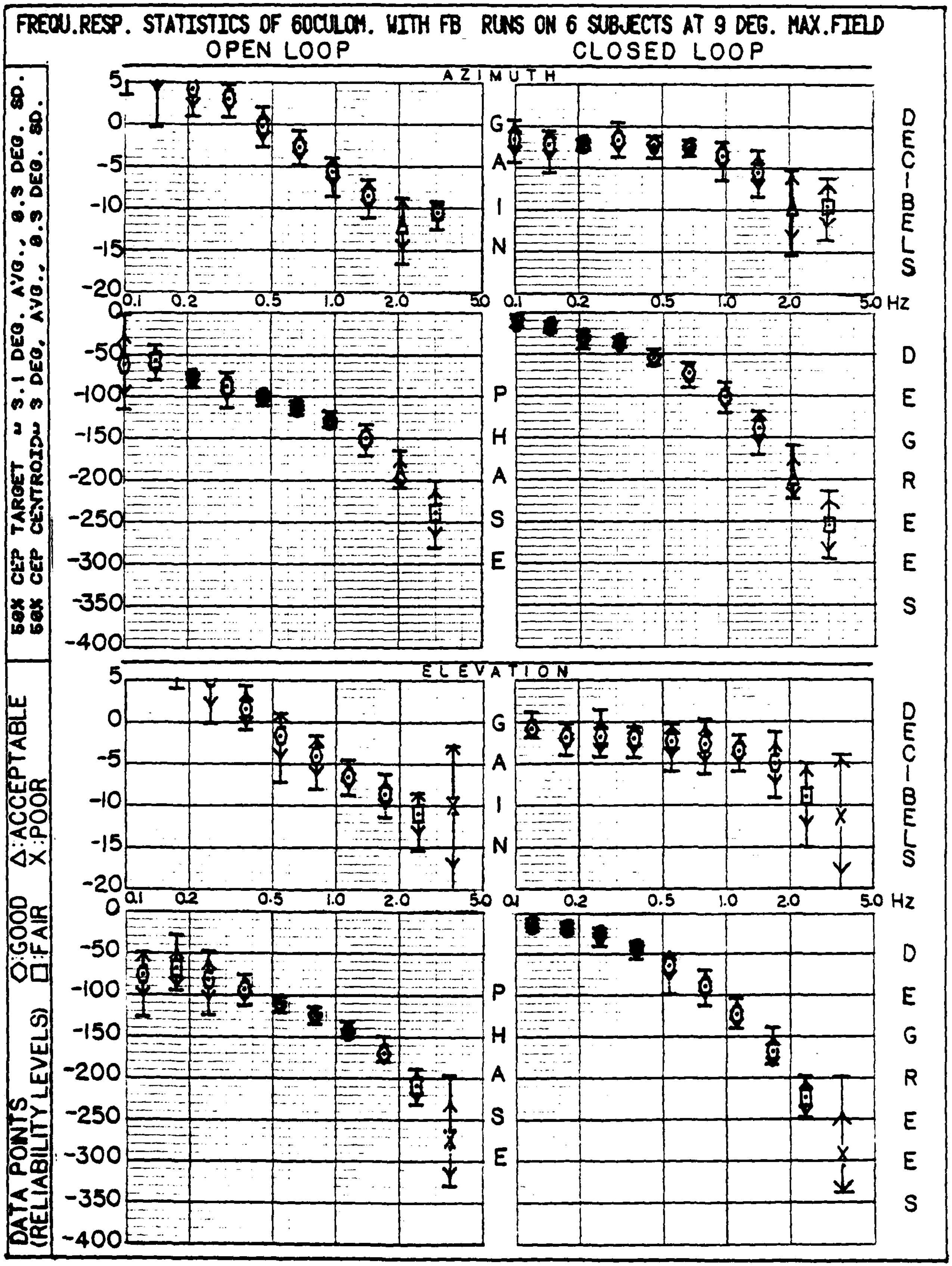
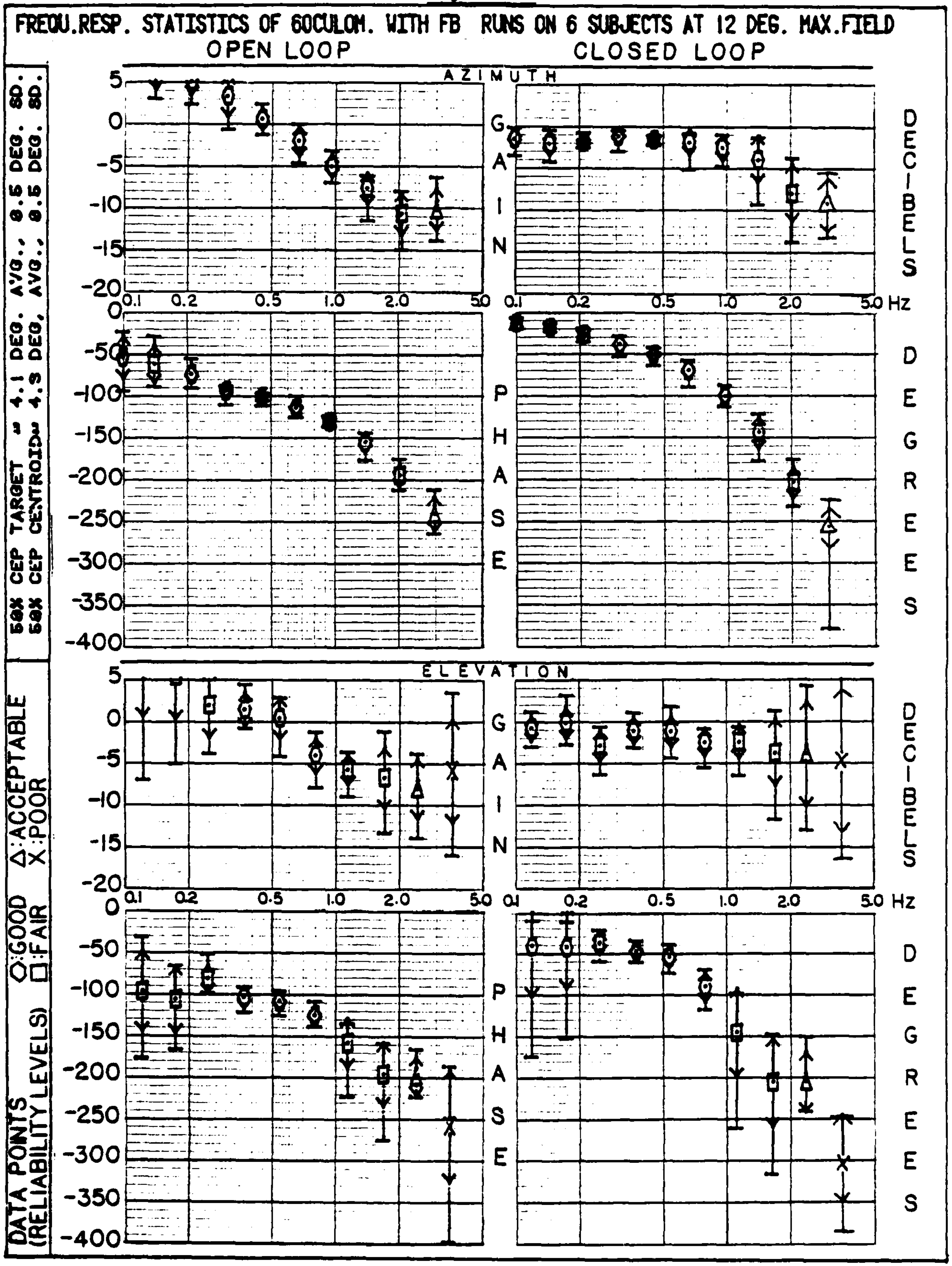

FREQU.RESP. STATISTICS OF 6OCULOM. WITH FB RUNS ON 6 SUBJECTS AT 9 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 3.1 DEG. AVG., 0.3 DEG. SD.
50% CEP CENTROID = 3 DEG. AVG., 0.3 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
O:GOOD □:FAIR
△:ACCEPTABLE X:POOR

Figure B-9



FREQU.RESP. STATISTICS OF 6OCULOM. WITH FB RUNS ON 6 SUBJECTS AT 12 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 4.1 DEG. AVG., 8.5 DEG. SD.
50% CEP CENTROID= 4.3 DEG, AVG., 8.5 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
◇:GOOD △:ACCEPTABLE
□:FAIR X:POOR

APPENDIX C

AVERAGED RESULTS OF 12 EOG TRACKING RUNS WITH BREAK FREQUENCY OD 1.0 HERTZ

For Subjects 1 and 2, 12 EOG tracking runs were performed with a target forcing function of 1.0 Hz break frequency. As can be noted from the individual tracking results for Subjects 1 and 2 (in Appendix A), *these data are not considered* reliable (see markings on the plots in terms of reliability levels). The break frequency of 1.0 Hz was evidently too high and was therefore lowered for the subsequent tracking runs. Nevertheless, the results of these 12 EOG tracking runs were averaged in groups of 5, 3 and 4 tracking runs for maximum target angles of 6. 9 and 12 degrees respectively.

The results are shown in Tables C-1 to C-3 and Figures C-1 to C-3 respectively.

Table C-1 (a)

FREQUENCY RESPONSE STATISTICS FOR 5 E O G RUNS AT 6 DEG MAX. FIELD
SUBJECT NO.: 1, 2,
NUMBER OF RUNS: 2+ 3+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 5RUNS
50% CEP TARGET : AVG.= 3.7 DEG, STD. DEV.= 0.2 DEG, RANGE: 3.4. . .4.0 DEG
50% CEP CENTROID: AVG.= 3.7 DEG, STD. DEV.= 0.2 DEG, RANGE: 3.4. . .3.9 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-9.2	-57.4	1.4	37.7	POOR	-10.7	-10.6	-7.8	-6.4	POOR	-98.3	-95.1	-19.6	6.1
0.143	-4.6	-70.5	2.4	47.3	POOR	-8.3	-7.0	-2.2	-1.7	POOR	-133.1	-117.8	-23.1	1.2
0.209	-5.3	-112.4	4.2	37.6	ACPT	-13.4	-9.5	-1.1	-1.7	ACPT	-187.3	-150.0	-74.7	-90.9
0.308	-7.7	-87.4	3.8	32.1	ACPT	-11.6	-11.5	-3.9	-0.7	ACPT	-138.2	-119.5	-55.3	-37.3
0.450	-4.1	-104.2	2.8	29.7	GOOD	-8.5	-6.9	-1.3	0.0	GOOD	-141.6	-133.9	-74.5	-71.3
0.659	-4.6	-143.3	4.7	17.4	FAIR	-11.0	-9.3	0.1	2.3	FAIR	-165.8	-160.7	-125.9	-122.5
0.967	-0.8	-187.7	1.4	9.7	GOOD	-2.9	-2.1	0.6	0.6	GOOD	-200.8	-197.4	-178.0	-172.6
1.406	-1.2	-248.2	1.8	8.2	GOOD	-3.4	-2.9	0.6	1.0	GOOD	-260.9	-256.4	-240.0	-236.2
2.055	-4.7	-298.3	1.3	16.9	FAIR	-6.7	-6.0	-3.4	-2.9	FAIR	-314.8	-315.1	-281.4	-270.0
3.000	-5.9	-352.2	2.6	11.1	FAIR	-10.4	-8.5	-3.2	-2.6	FAIR	-361.9	-363.3	-341.0	-330.5

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-8.2	-71.3	2.0	46.5	POOR	-10.2	-10.2	-6.2	-4.7	POOR	-116.1	-117.9	-24.8	9.7
0.143	-3.5	-109.1	4.6	159.8	POOR	-10.5	-8.1	1.1	2.7	POOR	-357.1	-268.9	50.8	145.7
0.209	-7.2	-138.8	4.0	23.9	ACPT	-15.1	-11.2	-3.2	-4.0	ACPT	-186.0	-162.7	-115.0	-120.8
0.308	-8.3	-108.9	3.1	32.8	ACPT	-13.2	-11.4	-5.3	-3.7	ACPT	-146.5	-141.7	-76.2	-51.9
0.450	-6.3	-129.1	1.4	25.5	GOOD	-8.1	-7.7	-5.0	-4.9	GOOD	-158.8	-154.5	-103.6	-93.3
0.659	-8.4	-157.6	3.1	11.5	FAIR	-12.5	-11.5	-5.3	-3.8	FAIR	-171.6	-169.0	-146.1	-137.9
0.967	-6.4	-184.1	0.7	5.1	GOOD	-7.6	-7.1	-5.7	-5.7	GOOD	-191.5	-189.2	-179.0	-176.3
1.406	-5.0	-217.1	0.8	7.8	GOOD	-6.4	-5.8	-4.2	-4.1	GOOD	-228.7	-224.9	-209.4	-207.4
2.055	-3.5	-263.5	2.1	15.6	FAIR	-6.4	-5.6	-1.3	-0.3	FAIR	-288.7	-279.1	-247.9	-241.3
3.000	-0.0	-340.8	4.0	28.7	FAIR	-7.3	-4.1	4.0	4.1	FAIR	-363.9	-369.5	-312.1	-284.5

Table C-1 (b)

FREQUENCY RESPONSE STATISTICS FOR 5 E D G RUNS AT 6 DEG MAX. FIELD
SUBJECT NO.: 1, 2,
NUMBER OF RUNS: 2+ 3+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 5RUNS
50% CEP TARGET : AVG.= 3.7 DEG, STD. DEV.= 0.2 DEG, RANGE: 3.4. . .4.0 DEG
50% CEP CENTROID: AVG.= 3.7 DEG, STD. DEV.= 0.2 DEG, RANGE: 3.4. . .3.9 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-5.3	-62.3	2.2	13.3	ACPT	-7.4	-7.5	-3.1	-1.4	ACPT	-79.4	-75.6	-49.0	-40.5
0.176	-6.4	-74.2	5.1	43.4	POOR	-15.5	-11.5	-1.3	-1.3	POOR	-132.2	-117.6	-30.8	-9.1
0.253	-9.5	-86.9	6.5	40.5	POOR	-21.5	-16.0	-3.0	-4.2	POOR	-136.6	-127.4	-46.3	-30.6
0.374	-7.5	-137.9	7.4	80.9	ACPT	-21.9	-14.9	-0.2	-1.8	ACPT	-293.6	-218.8	-57.0	-68.8
0.549	-4.2	-135.4	2.4	30.0	FAIR	-7.7	-6.6	-1.8	-1.0	FAIR	-192.8	-165.4	-105.4	-113.9
0.802	-2.9	-151.0	4.2	18.6	FAIR	-10.5	-7.1	1.3	1.9	FAIR	-175.8	-169.6	-132.4	-127.7
1.165	-2.4	-215.5	3.7	27.5	ACPT	-5.3	-6.1	1.2	3.9	ACPT	-244.8	-243.0	-187.9	-171.8
1.703	-4.1	-268.8	3.6	11.5	FAIR	-9.2	-7.7	-0.5	0.1	FAIR	-285.4	-280.3	-257.3	-251.8
2.483	-8.0	-339.3	4.2	25.7	ACPT	-14.8	-12.2	-3.8	-3.0	ACPT	-376.1	-365.0	-313.7	-306.0
3.626	-9.8	-416.2	3.9	41.1	POOR	-16.2	-13.7	-5.9	-6.5	POOR	-456.3	-457.3	-375.1	-348.2

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-4.4	-94.8	2.0	18.0	ACPT	-7.0	-6.4	-2.4	-1.4	ACPT	-115.5	-112.8	-76.8	-68.6
0.176	-4.3	-100.8	9.0	36.6	POOR	-15.4	-13.3	4.7	10.0	POOR	-148.2	-137.4	-64.2	-39.0
0.253	-9.5	-106.5	6.7	38.1	POOR	-22.0	-16.3	-2.8	-1.6	POOR	-139.7	-144.6	-68.5	-40.8
0.374	-9.0	-160.3	6.6	66.4	ACPT	-21.7	-15.6	-2.4	-3.5	ACPT	-289.2	-226.7	-93.9	-102.5
0.549	-7.5	-153.7	2.0	18.4	FAIR	-10.6	-9.4	-5.5	-5.1	FAIR	-189.0	-172.1	-135.3	-136.6
0.802	-7.4	-163.4	2.8	9.9	FAIR	-12.7	-10.2	-4.7	-5.1	FAIR	-178.2	-173.4	-153.5	-150.1
1.165	-6.9	-199.9	2.0	17.4	ACPT	-9.1	-8.9	-4.9	-3.3	ACPT	-223.1	-217.3	-182.6	-174.7
1.703	-5.8	-235.3	3.2	8.3	FAIR	-10.1	-8.9	-2.6	-1.6	FAIR	-245.6	-243.5	-227.0	-224.1
2.483	-3.2	-334.6	7.5	37.1	POOR	-14.0	-10.7	4.3	7.6	POOR	-395.7	-371.7	-297.5	-296.0
3.626	-9.1	-360.4	4.1	128.1	POOR	-14.8	-13.2	-5.0	-3.0	POOR	-473.0	-488.5	-232.3	-119.5

Table C-2 (a)

FREQUENCY RESPONSE STATISTICS FOR 3 E O G RUNS AT 9 DEG MAX. FIELD
SUBJECT NO.: 1, 2,
NUMBER OF RUNS: 2+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 3RUNS
50% CEP TARGET : AVG.= 5.8 DEG, STD. DEV.= 0.3 DEG, RANGE: 5.5. . .6.2 DEG
50% CEP CENTROID: AVG.= 5.7 DEG, STD. DEV.= 0.3 DEG, RANGE: 5.4. . .6.2 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-8.8	-79.4	5.4	58.4	ACPT	-16.4	-14.2	-3.4	-4.8	ACPT	-162.0	-137.8	-20.9	-38.0
0.143	-12.7	-154.6	4.2	33.7	POOR	-18.4	-16.9	-8.5	-8.5	POOR	-182.7	-188.3	-121.0	-107.3
0.209	-8.3	-98.7	6.6	46.6	POOR	-16.7	-14.8	-1.7	-0.7	POOR	-135.8	-145.3	-52.0	-32.9
0.308	-6.1	-127.1	3.3	39.3	ACPT	-10.2	-9.5	-2.8	-2.0	ACPT	-180.3	-166.4	-87.8	-86.6
0.450	-7.7	-129.8	7.2	30.4	ACPT	-17.8	-14.9	-0.5	-2.1	ACPT	-171.2	-160.1	-99.4	-99.2
0.659	-2.7	-141.1	5.6	15.6	FAIR	-10.4	-8.3	2.8	2.7	FAIR	-161.0	-156.8	-125.5	-122.8
0.967	-2.6	-193.2	3.6	4.9	GOOD	-7.6	-6.2	1.0	0.7	GOOD	-196.7	-198.0	-188.3	-186.3
1.406	-2.8	-257.1	1.9	4.1	GOOD	-4.3	-4.7	-1.0	-0.2	GOOD	-262.8	-261.1	-253.0	-254.0
2.055	-6.1	-302.0	4.1	11.5	GOOD	-11.9	-10.2	-1.9	-2.6	GOOD	-317.2	-313.5	-290.5	-289.4
3.000	-7.7	-346.8	2.8	9.1	FAIR	-11.6	-10.5	-4.9	-5.4	FAIR	-354.9	-355.9	-337.7	-334.1

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-6.7	-101.6	7.7	44.4	ACPT	-17.6	-14.4	1.0	-1.0	ACPT	-164.4	-146.0	-57.1	-68.9
0.143	-14.4	-156.9	3.1	30.7	POOR	-18.7	-17.6	-11.3	-11.3	POOR	-181.9	-187.6	-126.2	-113.6
0.209	-9.1	-114.4	6.0	44.6	POOR	-17.5	-15.1	-3.1	-4.1	POOR	-157.0	-159.0	-69.8	-52.8
0.308	-8.3	-145.5	3.0	27.4	ACPT	-12.5	-11.3	-5.3	-5.6	ACPT	-180.3	-172.9	-118.2	-113.4
0.450	-10.1	-149.4	6.2	17.2	ACPT	-18.9	-16.3	-3.9	-5.5	ACPT	-172.2	-166.6	-132.3	-130.7
0.659	-7.5	-156.1	3.2	15.1	FAIR	-11.9	-10.7	-4.2	-4.3	FAIR	-170.2	-171.2	-141.0	-135.1
0.967	-7.5	-187.7	2.1	3.5	GOOD	-10.5	-9.7	-5.4	-5.6	GOOD	-191.8	-191.1	-184.2	-183.3
1.406	-5.6	-226.0	1.0	6.3	GOOD	-6.6	-6.6	-4.6	-4.2	GOOD	-232.7	-232.2	-219.7	-217.6
2.055	-5.3	-270.4	3.5	25.2	GOOD	-10.2	-8.8	-1.8	-2.7	GOOD	-305.2	-295.6	-245.2	-246.6
3.000	-3.1	-335.8	4.3	17.2	FAIR	-9.0	-7.4	1.1	1.0	FAIR	-353.1	-353.0	-318.6	-312.3

Table C-2 (b)

FREQUENCY RESPONSE STATISTICS FOR 3 E O G RUNS AT 9 DEG MAX. FIELD
SUBJECT NO.: 1, 2,
NUMBER OF RUNS: 2+ 1+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 3RUNS
50% CEP TARGET : AVG.= 5.8 DEG, STD. DEV.= 0.3 DEG, RANGE: 5.5. . .6.2 DEG
50% CEP CENTROID: AVG.= 5.7 DEG, STD. DEV.= 0.3 DEG, RANGE: 5.4. . .6.2 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-2.3	-132.3	2.6	132.5	GOOD	-4.2	-4.9	0.3	1.4	GOOD	-319.7	-264.8	0.2	-35.9
0.176	-4.5	-84.4	0.9	73.1	POOR	-5.2	-5.4	-3.6	-3.2	POOR	-186.4	-157.5	-11.3	-19.2
0.253	-4.3	-86.0	1.5	55.0	POOR	-6.0	-5.8	-2.8	-2.3	POOR	-152.1	-140.9	-31.0	-17.5
0.374	-7.1	-119.4	4.5	58.1	ACPT	-11.7	-11.6	-2.6	-1.0	ACPT	-199.5	-177.5	-61.3	-63.5
0.549	-5.2	-106.6	2.3	44.1	ACPT	-8.3	-7.5	-2.9	-3.0	ACPT	-156.0	-150.7	-62.5	-49.0
0.802	-3.1	-129.5	4.8	51.6	FAIR	-9.7	-7.9	1.7	1.5	FAIR	-182.9	-181.1	-77.9	-59.7
1.165	-3.8	-196.1	7.6	16.0	FAIR	-14.5	-11.4	3.8	1.9	FAIR	-211.7	-212.2	-180.1	-174.1
1.703	-3.5	-265.9	2.1	16.4	GOOD	-6.3	-5.6	-1.3	-1.1	GOOD	-283.3	-282.3	-249.6	-244.0
2.483	-5.3	-354.7	3.3	20.8	FAIR	-9.5	-8.6	-2.0	-1.5	FAIR	-382.9	-375.6	-333.9	-333.2
3.626	-8.9	-416.0	1.4	20.0	ACPT	-10.8	-10.3	-7.6	-7.6	ACPT	-440.3	-435.9	-396.0	-391.4

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	1.0	-129.4	1.9	76.3	GOOD	-0.7	-0.9	2.9	3.7	GOOD	-237.3	-205.8	-53.1	-72.1
0.176	-3.3	-101.5	3.5	60.5	POOR	-7.8	-6.7	0.2	0.6	POOR	-183.8	-162.1	-41.0	-39.9
0.253	-3.9	-109.1	4.6	51.3	POOR	-9.3	-8.4	0.7	1.9	POOR	-161.4	-160.4	-57.8	-39.4
0.374	-8.7	-135.8	3.4	47.3	ACPT	-11.2	-12.0	-5.3	-3.9	ACPT	-194.2	-183.1	-88.4	-78.3
0.549	-7.0	-124.9	0.5	40.2	ACPT	-7.5	-7.5	-6.5	-6.4	ACPT	-165.9	-165.1	-84.6	-70.2
0.802	-6.7	-141.5	1.5	45.1	FAIR	-8.6	-8.2	-5.2	-4.9	FAIR	-181.5	-186.6	-96.4	-78.5
1.165	-8.7	-186.6	5.2	8.4	FAIR	-16.0	-13.9	-3.5	-5.0	FAIR	-194.7	-195.0	-178.2	-175.0
1.703	-5.3	-232.3	2.3	8.4	GOOD	-8.5	-7.6	-3.0	-3.6	GOOD	-243.9	-240.7	-223.9	-224.2
2.483	1.5	-334.1	7.1	42.0	POOR	-6.5	-5.6	8.5	10.7	POOR	-393.5	-376.1	-292.1	-303.3
3.626	-7.3	-434.9	2.7	19.2	ACPT	-10.8	-10.0	-4.6	-4.2	ACPT	-456.8	-454.1	-415.8	-410.1

Table C-3 (a)

FREQUENCY RESPONSE STATISTICS FOR 4 E O G RUNS AT 12 DEG MAX. FIELD
SUBJECT NO.: 1, 2,
NUMBER OF RUNS: 2+ 2+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 4RUNS
50% CEP TARGET : AVG.= 7.3 DEG, STD. DEV.= 0.7 DEG, RANGE: 6.6. . .8.3 DEG
50% CEP CENTROID: AVG.= 7.3 DEG, STD. DEV.= 0.7 DEG, RANGE: 6.5. . .8.3 DEG

AZIMUTH CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-5.3	-96.7	2.7	48.5	FAIR	-8.1	-8.0	-2.6	-1.2	FAIR	-143.5	-145.2	-48.2	-31.7
0.143	-6.6	-134.3	7.7	97.9	ACPT	-19.1	-14.3	1.1	-0.1	ACPT	-288.9	-232.2	-36.4	-30.1
0.209	-7.9	-111.5	4.0	36.3	POOR	-11.5	-11.9	-3.9	-1.1	POOR	-147.6	-147.9	-75.2	-57.0
0.308	-5.2	-114.3	4.5	48.5	ACPT	-12.1	-9.7	-0.7	-1.0	ACPT	-195.5	-162.8	-65.8	-74.3
0.450	-7.4	-136.2	4.4	50.6	FAIR	-12.1	-11.8	-3.0	-1.2	FAIR	-212.6	-186.9	-85.6	-74.8
0.659	-5.1	-142.7	3.7	29.8	GOOD	-10.5	-8.8	-1.3	-0.5	GOOD	-179.0	-172.5	-112.9	-97.6
0.967	-2.6	-190.8	1.1	10.2	FAIR	-3.7	-3.7	-1.6	-0.9	FAIR	-205.6	-201.0	-180.6	-176.9
1.406	-3.8	-249.3	2.6	4.7	GOOD	-7.5	-6.4	-1.2	-1.0	GOOD	-256.8	-254.0	-244.6	-243.8
2.055	-4.1	-301.3	1.1	12.7	GOOD	-5.7	-5.1	-3.0	-2.9	GOOD	-314.9	-314.0	-288.7	-280.9
3.000	-8.4	-362.5	2.4	13.0	GOOD	-12.0	-10.8	-6.0	-5.4	GOOD	-373.7	-375.5	-349.5	-340.4

AZIMUTH OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.100	-5.9	-40.0	3.6	117.7	FAIR	-10.0	-9.6	-2.3	-0.1	FAIR	-160.4	-157.7	77.7	154.3
0.143	-7.3	-155.1	6.7	83.8	ACPT	-18.8	-14.1	-0.6	-2.0	ACPT	-282.7	-238.9	-71.4	-50.8
0.209	-8.8	-133.7	5.1	18.9	POOR	-13.3	-14.0	-3.7	-0.2	POOR	-154.2	-152.6	-114.8	-112.1
0.308	-6.9	-140.2	4.2	33.1	ACPT	-14.0	-11.2	-2.7	-2.9	ACPT	-192.4	-173.4	-107.1	-102.2
0.450	-9.6	-147.8	2.8	42.2	FAIR	-12.9	-12.4	-6.8	-6.2	FAIR	-205.6	-190.0	-105.6	-89.2
0.659	-8.4	-154.5	2.5	20.8	GOOD	-12.7	-10.9	-5.9	-6.3	GOOD	-179.5	-175.4	-133.7	-122.0
0.967	-7.4	-186.3	0.6	6.2	FAIR	-7.8	-8.0	-6.8	-6.4	FAIR	-195.5	-192.5	-180.2	-178.2
1.406	-6.7	-223.2	1.7	7.3	GOOD	-9.3	-8.4	-5.0	-4.9	GOOD	-231.0	-230.5	-215.9	-215.5
2.055	-2.8	-264.1	0.9	15.1	GOOD	-3.9	-3.7	-1.9	-1.4	GOOD	-284.6	-279.2	-249.0	-241.9
3.000	-4.3	-361.2	3.5	23.6	GOOD	-9.6	-7.8	-0.8	0.1	GOOD	-378.2	-384.8	-337.7	-320.6

Table C-3 (b)

FREQUENCY RESPONSE STATISTICS FOR 4 E O G RUNS AT 12 DEG MAX. FIELD
SUBJECT NO.: 1, 2,
NUMBER OF RUNS: 2+ 2+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+ 0+= 4RUNS
50% CEP TARGET : AVG.= 7.3 DEG, STD. DEV.= 0.7 DEG, RANGE: 6.6. . .8.3 DEG
50% CEP CENTROID: AVG.= 7.3 DEG, STD. DEV.= 0.7 DEG, RANGE: 6.5. . .8.3 DEG

ELEVATION CLOSED LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-8.4	-45.3	3.1	53.4	ACPT	-11.7	-11.5	-5.4	-3.4	ACPT	-120.0	-98.7	8.1	31.0
0.176	-5.8	-116.6	4.7	71.0	FAIR	-10.8	-10.5	-1.1	1.9	FAIR	-221.4	-187.6	-45.6	-30.8
0.253	-12.1	-174.7	7.0	79.7	POOR	-20.9	-19.1	-5.1	-3.0	POOR	-309.3	-254.4	-95.0	-107.8
0.374	-8.1	-133.2	4.5	55.7	ACPT	-15.6	-12.6	-3.6	-4.1	ACPT	-225.8	-188.9	-77.5	-83.7
0.549	-10.9	-168.8	5.8	33.2	POOR	-18.0	-16.8	-5.1	-2.7	POOR	-210.0	-202.0	-135.6	-122.2
0.802	-5.6	-169.1	2.6	9.1	GOOD	-9.5	-8.2	-3.1	-2.5	GOOD	-181.0	-178.2	-160.0	-155.6
1.165	-4.2	-201.6	3.0	17.4	GOOD	-9.2	-7.2	-1.2	-1.1	GOOD	-225.2	-218.9	-184.2	-176.5
1.703	-4.5	-270.2	1.5	9.1	GOOD	-7.1	-6.0	-3.0	-3.2	GOOD	-281.2	-279.3	-261.1	-260.3
2.483	-7.8	-331.1	1.9	16.3	GOOD	-10.3	-9.7	-5.9	-5.3	GOOD	-356.9	-347.4	-314.8	-311.8
3.626	-10.8	-393.1	3.5	11.1	FAIR	-16.0	-14.3	-7.3	-6.3	FAIR	-404.3	-404.3	-382.0	-376.6

ELEVATION OPEN LOOP

	AVERAGE		STAND. DEV.		GAIN-VARIATION					PHASE-VARIATION				
FREQU. (HERTZ)	GAIN (DB)	PHASE (DEG)	GAIN (DB)	PHASE (DEG)	REL. LEV.	MIN (DB)	AV-SD (DB)	AV+SD (DB)	MAX (DB)	REL. LEV.	MIN (DEG)	AV-SD (DEG)	AV+SD (DEG)	MAX (DEG)
0.121	-6.7	-46.6	5.1	73.9	ACPT	-10.8	-11.8	-1.7	1.8	ACPT	-134.5	-120.5	27.3	70.3
0.176	-6.0	-145.7	7.0	39.4	FAIR	-12.5	-13.0	1.0	5.8	FAIR	-208.5	-185.2	-106.3	-101.7
0.253	-13.5	-181.3	5.4	72.1	POOR	-21.1	-19.0	-8.1	-6.6	POOR	-302.0	-253.4	-109.3	-112.5
0.374	-9.5	-150.3	4.3	41.4	ACPT	-16.6	-13.8	-5.3	-5.9	ACPT	-219.7	-191.8	-108.9	-112.5
0.549	-13.1	-175.0	4.7	22.7	POOR	-19.0	-17.8	-8.4	-6.4	POOR	-205.3	-197.8	-152.3	-146.2
0.802	-9.3	-172.6	1.7	6.0	GOOD	-12.0	-11.0	-7.5	-7.3	GOOD	-180.6	-178.7	-166.6	-163.6
1.165	-8.3	-193.3	2.0	10.4	GOOD	-11.7	-10.3	-6.2	-6.4	GOOD	-207.3	-203.7	-182.9	-178.0
1.703	-5.9	-239.6	1.0	10.0	GOOD	-7.2	-6.9	-4.9	-4.4	GOOD	-255.8	-249.7	-229.6	-230.2
2.483	-4.8	-313.3	1.9	27.3	GOOD	-7.2	-6.7	-2.9	-2.8	GOOD	-355.6	-340.6	-286.0	-279.2
3.626	-8.2	-405.6	4.9	12.9	FAIR	-14.8	-13.1	-3.4	-1.1	FAIR	-421.1	-418.5	-392.6	-391.1

Figure C-1

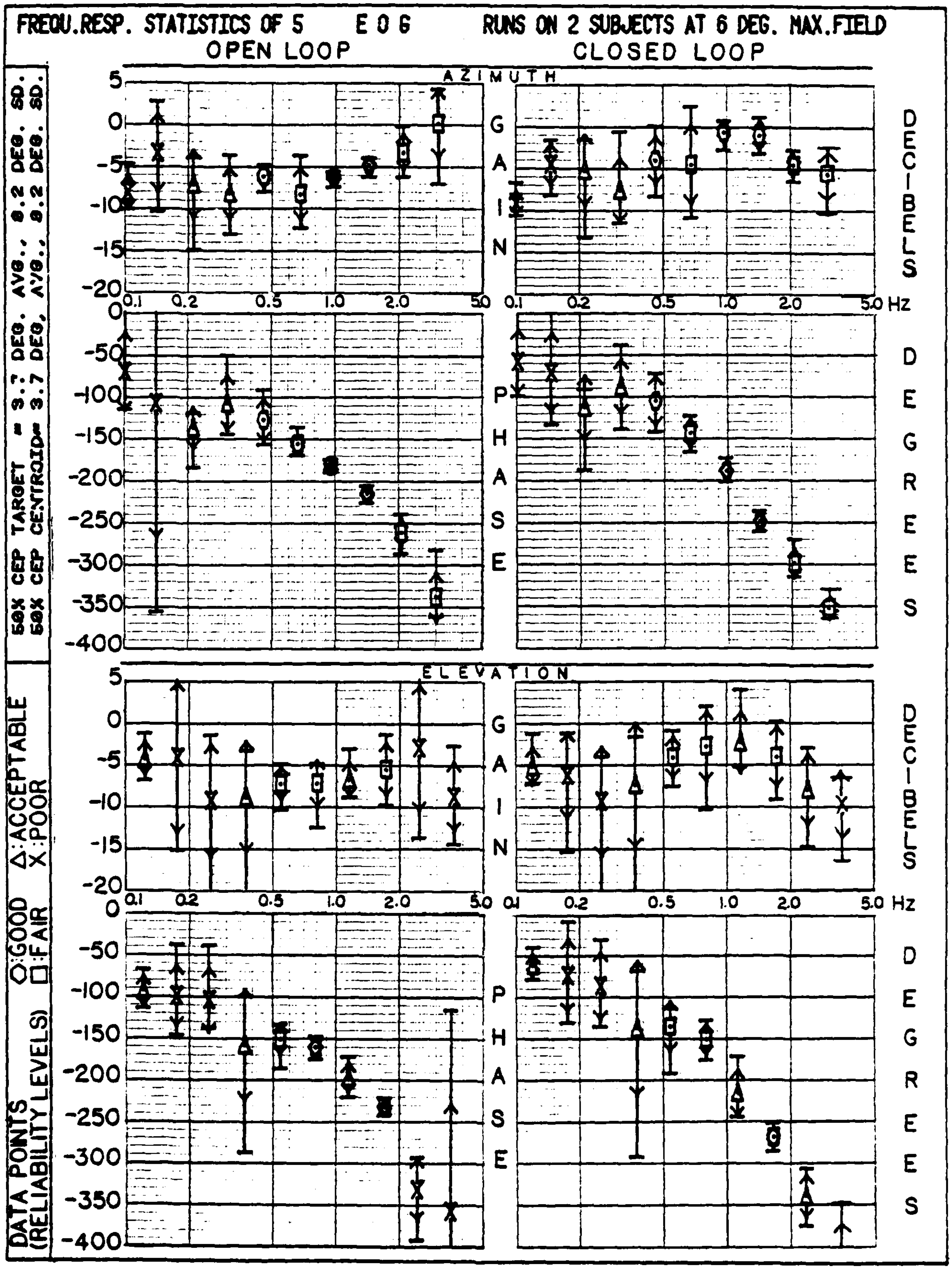

FREQU.RESP. STATISTICS OF 5 E O G RUNS ON 2 SUBJECTS AT 6 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 3.7 DEG. AVG., 8.2 DEG. SD.
50% CEP CENTROID= 3.7 DEG, AVG., 8.2 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
O:GOOD □:FAIR
Δ:ACCEPTABLE X:POOR

Figure C-2

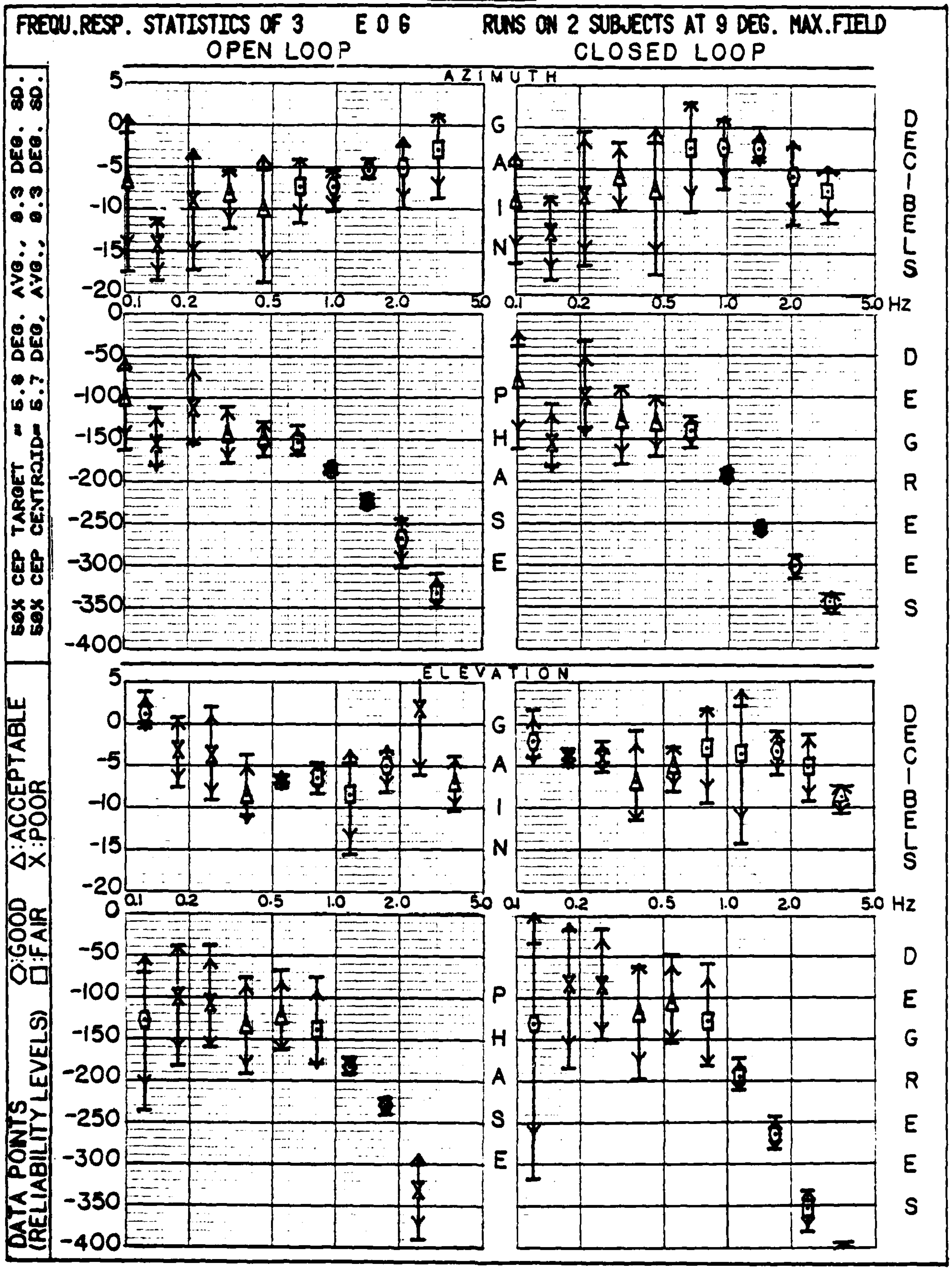
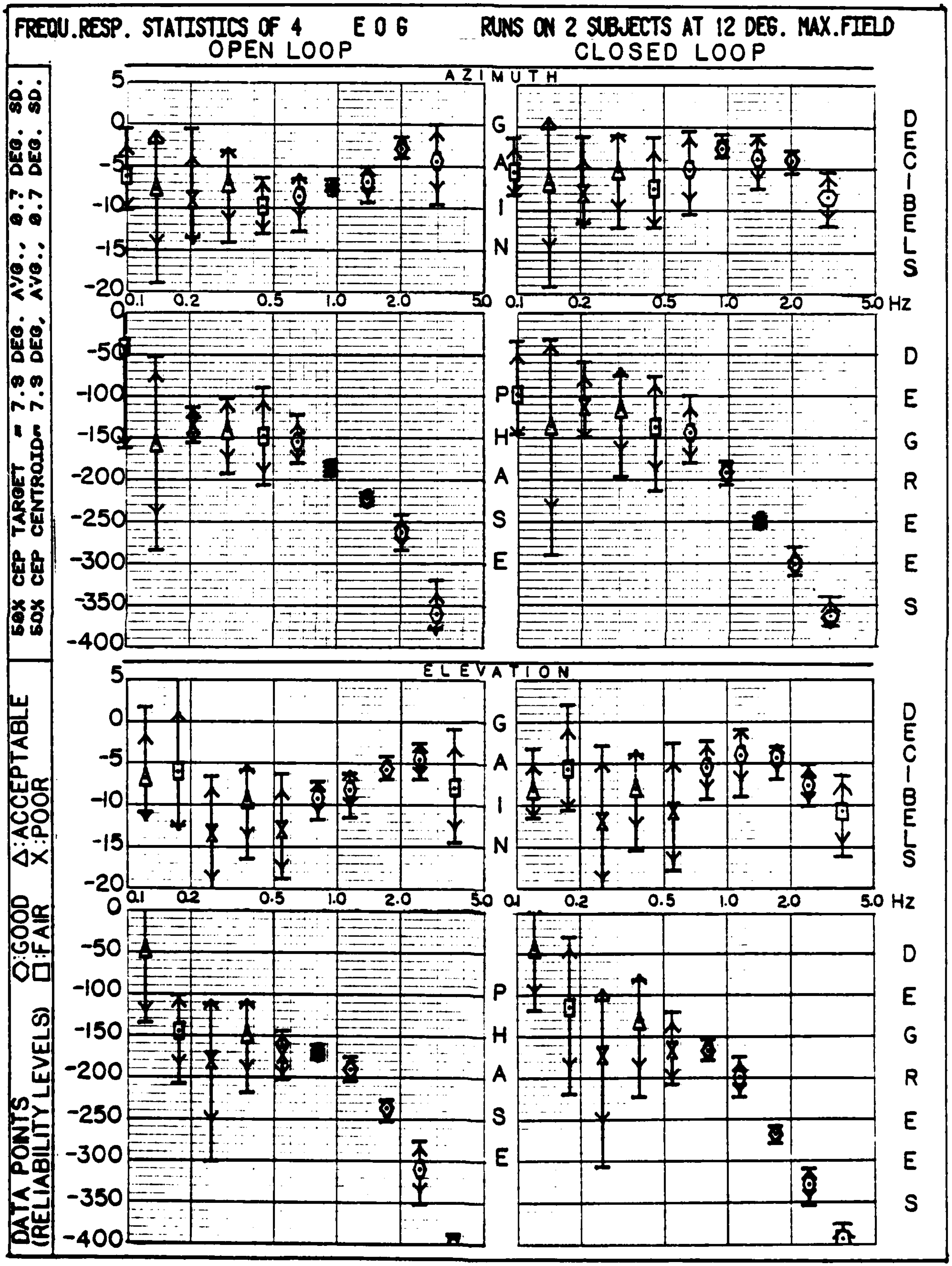

FREQU.RESP. STATISTICS OF 3 E O G RUNS ON 2 SUBJECTS AT 9 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 5.8 DEG. AVG., 8.3 DEG. SD.
50% CEP CENTROID= 5.7 DEG. AVG., 8.3 DEG. SD.
Δ:ACCEPTABLE
X:POOR
O:GOOD
□:FAIR
DATA POINTS
(RELIABILITY LEVELS)

Figure C-3


FREQU.RESP. STATISTICS OF 4 E O G RUNS ON 2 SUBJECTS AT 12 DEG. MAX.FIELD
OPEN LOOP
CLOSED LOOP
AZIMUTH
ELEVATION
GAIN
PHASE
DECIBELS
DEGREES
Hz
50% CEP TARGET = 7.9 DEG, AVG., 8.7 DEG. SD.
50% CEP CENTROID= 7.9 DEG, AVG., 8.7 DEG. SD.
DATA POINTS (RELIABILITY LEVELS)
◇:GOOD △:ACCEPTABLE
□:FAIR X:POOR

DATE
FILMED
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